VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. LV.—JULY, 1873.—Vol. IX.

ON COMPOUND ENGINES.

From "Naval Science."

The action of steam in a pair of simple or non-compound engines can be predicted with certainty, and the indicator diagrams which describe its varying pressure and volume can be constructed with very sufficient approximation to the actual performance, when the size of the cylinders, and the rates of expansion are determined. But we know of no published rules which will accomplish the same results for that most important class of compound engines—viz.: those fitted with a receiver.

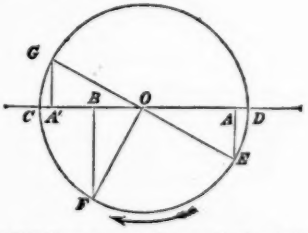
The horse-power developed will be independent (with one slight exception, to be noticed afterwards) of the *relative* volumes of the cylinders, of the size of the receiver, and of the cut-off in the low-pressure cylinder. At the same time the pressure at any point of the stroke will be affected by each of these considerations—so also will the *mean* forward pressure in the one cylinder, and the *mean* back pressure in the other. Upon the choice of these quantities will depend, then, the proportion of work done in each cylinder, and consequently the value of the maximum strains on the piston and shafting—in short, the efficiency of the engine. We propose in this article to investigate a formula which shall determine the pressure at any part of the stroke; by aid of this to construct the indicator diagrams corresponding to various proportions of cylinders and points of cut-off in the large cylinder, preserving the same total ratio of expansion and the same horse-power; to discuss the effects of these proportions, first, on the division of work between the two cylinders; next, on the maximum straining effect on the piston; and lastly, on the maximum torsion of the shafting.

For greater simplicity it will be convenient to neglect the obliquity of the connecting rod, and also to suppose all the steam exhausted at the end of the stroke.

The value of the cut-off used will represent the real effective cut-off—that is, where allowance has been made for wire drawing, clearance, and cushioning. The expansion of the steam is supposed to take place according to the hyperbolic law.

In every case considered there are two cylinders with cranks at right angles and an intermediate receiver.

The position of either piston corresponding to any angle of the cranks must first be determined.



Let C F E D represent the crank pin circle.
C D represent the centre line of cylinder.
O E be the position of one crank (that of the low pressure cylinder for instance).
O F that of the other.
$\angle$ D O E = θ.

If θ be less than 90°:—
Portion of stroke performed by low-pressure piston

$$= \frac{A\,D}{C\,D} = \frac{\text{vers}\,\theta}{2},$$

Portion of stroke performed by high pressure piston

$$= \frac{B\,D}{C\,D} = \frac{1+\sin\theta}{2}.$$

If θ be greater than 90 deg. and O F, O G be the cranks, and $\angle$ D O F $= \theta$:—
Portion of stroke performed by low-pressure piston.

$$= \frac{B\,D}{C\,D} = \frac{\text{vers}\,\theta}{2}$$

Portion performed by the high pressure piston.

$$= \frac{A'\,C}{C\,D} = \frac{1-\sin\theta}{2}$$

Let

$$\frac{A\,D}{C\,D} = \frac{1}{q}, \text{ then vers } \theta = \frac{2}{q},$$

and

$$\frac{1+\sin\theta}{2} = \frac{q+2\sqrt{q-1}}{2q},$$

$$\frac{1-\sin\theta}{2} = \frac{q-2\sqrt{q-1}}{2q}.$$

That is to say, that, if the steam is cut off at $\frac{1}{q}$th of the stroke on the low-pressure cylinder, the piston of the high pressure cylinder has passed through the $\frac{q-2\sqrt{q-1}}{2q}$th or $\frac{q+2\sqrt{q-1}}{2q}$th part of its stroke, according as the steam is cut off after or before half stroke in the low-pressure cylinder; or, which is the same thing, according as q is less or greater than 2.

Let A be the volume of the high-pressure cylinder.
C " " " low-pressure cylinder.
B " " " receiver.
r the total ratio of expansion.

Then $\frac{r\,A}{C}$ will be the ratio of expansion in the high-pressure cylinder.

Let q be the ratio of expansion in the low-pressure cylinder—that is, let the steam be cut off at $\frac{1}{q}$th the stroke; and let P be the initial absolute pressure of steam.

First, suppose q less than 2. Then for $\frac{q-2\sqrt{q-1}}{2q}$, writing $1-l$, where $l = \frac{q+2\sqrt{q-1}}{2q}$, we see that as P is the initial forward pressure in A, and as the steam is expanded $\frac{r\,A}{C}$ times in A, the terminal pressure in that cylinder will be $\frac{P\,C}{r\,A}$. Again, since the total ratio of expansion is r, the terminal pressure in C will be $\frac{P}{r}$; and as the steam is cut off in C at $\frac{1}{q}$th of its stroke the pressure in C and therefore also in B at the instant of cut-off will be $\frac{P\,q}{r}$. (1.)

At this instant there will be steam at pressure $\frac{P\,q}{r}$ occupying the volume $B+l\,A$. At the beginning of the next stroke of C this steam will occupy the space $B+\frac{A}{2}$; its pressure therefore will be

$$\frac{P\,q}{r}\,\frac{B+l\,A}{B+\frac{A}{2}} \qquad (2.)$$

At any intermediate part of the stroke of C corresponding to $\angle$ D O F $= \theta$ made by the low-pressure crank the space occupied by the steam will be

$$B + A\left(1 - \frac{1-\sin\theta}{2}\right);$$

hence the pressure in B will be

$$\frac{P\,q}{r}\,\frac{B+l\,A}{B+A\left(\frac{1+\sin\theta}{2}\right)}. \qquad (3.)$$

Just before half-stroke of C this steam occupies the space $B+\frac{C}{2}$, its pressure is therefore

$$\frac{P\,q}{r}\,\frac{B+l\,A}{B+\frac{C}{2}}. \qquad (4.)$$

For any point of stroke from the beginning and half stroke of C, the steam occupies the space

$$B + \frac{C\ \text{vers}\,\theta}{2} + A\,\frac{1-\sin\theta}{2}$$

The pressure in B becomes accordingly

$$\frac{P\,q}{r}\,\frac{B+l\,A}{B+\frac{C\ \text{vers}\,\theta}{2}+A\,\frac{1-\sin\theta}{2}} \qquad (5.)$$

At half-stroke of C, communication is made between B and A, the latter of which contains a volume (A) of steam at a pressure $\frac{P\,C}{r\,A}$; the pressure in B will then become

$$\frac{\frac{P\,q}{r}\left(\frac{B+l\,A}{B+\frac{C}{2}}\right)\left(B+\frac{C}{2}\right)+A\frac{P\,C}{r}}{B+\frac{C}{2}+A}=\frac{\frac{P\,q}{r}(B+l\,A)+\frac{P\,C}{r}}{A+B+\frac{C}{2}}. \quad (6.)$$

Just before the cut-off in C this steam occupies the space

$$B+\frac{C}{q}+A\,l,$$

and its pressure is

$$\frac{\frac{P\,q}{r}(B+l\,A)+\frac{P\,C}{r}}{B+\frac{C}{q}+l\,A}=\frac{P\,q}{r} \quad (7.)$$

Between half-stroke of C and the point of cut-off, the space occupied by the steam corresponding to the angle θ made by the low-pressure crank is

$$B+\frac{C\ \mathrm{vers}\,\theta}{2}+A\left(\frac{1+\sin\theta}{2}\right),$$

and the pressure is

$$\frac{\frac{P\,q}{r}(B+l\,A)+\frac{P\,C}{r}}{B+\frac{C\ \mathrm{vers}\,\theta}{2}+A\frac{1+\sin\theta}{2}} \quad (8.)$$

From the cut-off until the end of the stroke the whole volume in connection with B is

$$B+A\frac{(1+\sin\theta}{2},$$

The pressure in B is therefore

$$\frac{P\,q}{r}\,\frac{B+l\,A}{B+A\left(\frac{1+\sin\theta}{2}\right)}. \quad (9.)$$

Formulæ 1 to 9 are sufficient to determine the receiver pressure corresponding to any part of the stroke in either cylinder, when the cut-off in the low pressure cylinder takes place after the exhaust from the high.

Next consider the case when q is greater than 2.

Writing $1-l'$ for

$$\frac{q+2\sqrt{q-1}}{2\,q},\ \text{so that}\ l'=\frac{q-2\sqrt{q-1}}{2\,q},$$

we shall have as before

$$\text{Terminal pressure in A}=\frac{P\,C}{r\,A},$$

$$\text{“ “ “ C}=\frac{P\,C}{r},$$

$$\text{Pressure at cut-off in C}=\frac{P\,q}{r}. \quad (10.)$$

Reasoning as before, just before half-stroke the pressure becomes

$$\frac{P\,q}{r}\,\frac{B+l'\,A}{B}. \quad (11.)$$

At any point intermediate between cut-off and half stroke of C the pressure is

$$\frac{P\,q}{r}\,\frac{B+l'\,A}{B+A\frac{1-\sin\theta}{2}}. \quad (12.)$$

At half-stroke in C the exhaust from A takes place and the pressure rises to

$$\frac{\frac{P\,q}{r}(B+l'\,A)+\frac{P\,C}{r}}{A+B} \quad (13.)$$

The initial pressure in C is

$$\frac{\frac{P\,q}{r}(B+l'\,A)+\frac{P\,C}{r}}{B+\frac{A}{2}} \quad (14.)$$

At any intermediate point between half-stroke and the end of the stroke in C, the pressure is

$$\frac{\frac{P\,q}{r}(B+l'A)+\frac{P\,C}{r}}{B+A\frac{(1-\sin\theta}{2}}. \quad (15.)$$

At any point before the cut-off the pressure is

$$\frac{\frac{P\,q}{r}(B+l'\,A)+\frac{P\,C}{r}}{B+\frac{C\ \mathrm{vers}\,\theta}{2}+A\left(\frac{1-\sin\theta}{2}\right)} \quad (16.)$$

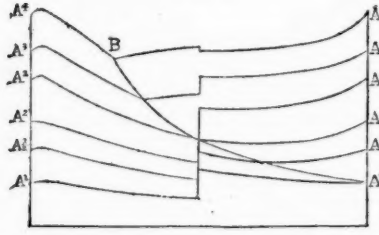
Formulæ 10 to 16 give the pressure in the receiver, corresponding to any part of the stroke in either cylinder, when the exhaust from the high-pressure cylinder takes place after the cut-off in the low.

By finding the pressure at a sufficient number of points the theoretical indicator diagrams of each cylinder can be calculated. But in these diagrams allowance must be made for the imperfect vacuum in the low-pressure-cylinder, and for the loss between the two engines by wire-drawing and radiation from the receiver.

The curves drawn, Figs. 1 to 8, are examples of these diagrams; the opposite curves with the same letters are identical, but these on the left-hand side are drawn so as to show the forward pressure in C; those on the right-hand to show the back pressure in A. The middle points of the

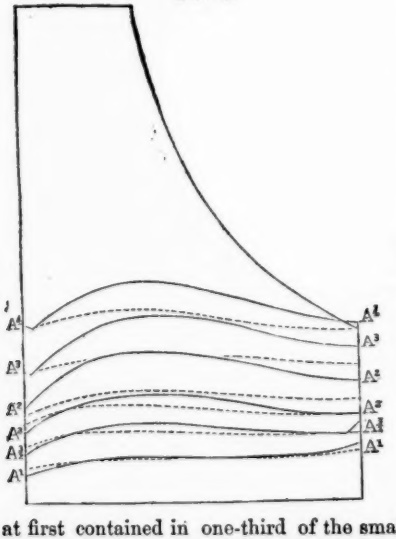
latter diagrams will agree with the beginning and end of the former. The first four diagrams represent in each case a total expansion of 12 times; the second four are drawn under the same conditions as the first, except that the total expansion is 6 times. This total expansion will be the

FIG. 1.



product of the expansion in the small cylinder and of the relative volumes of the two cylinders—for example, if the steam be cut off at one-third stroke on the first cylinder, and the volumes are as 4 : 1, since all the steam admitted must be used up in the stroke, it follows that the steam which was

FIG. 2.



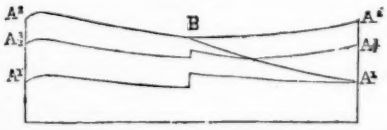
at first contained in one-third of the small finally occupies the whole of the large cylinder, and has consequently been expanded to 12 times its original volume—the total expansion is then perfectly independent of the cut-off in the large cylinder.

In Figs. 1 and 2, 5 and 6, the volumes of the cylinders are as 4 : 1—that is, $\frac{C}{A} = 4$.

In Figs. 3 and 4, 7 and 8, $\frac{C}{A} = 2$.

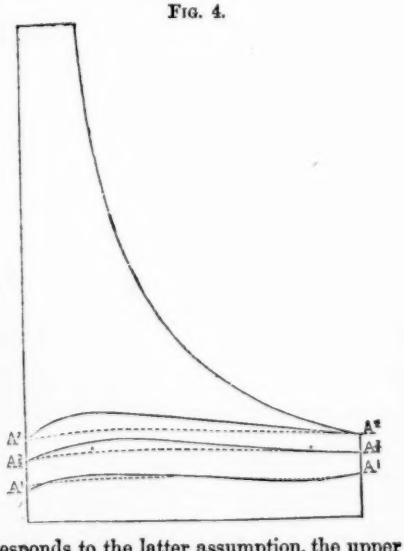
The various curves in each figure correspond to different volumes of q, or ratios

FIG. 3.



of expansion in the low-pressure cylinder. Thus A_1 A_1 represents the pressure in the receiver when steam is maintained throughout the stroke of C—that is, when $q = 1$. A_3 A_3 corresponds to the case when the connection with the receiver is closed at one-third stroke, or when $q = 3$. If $q = 2$, one piston will be at the middle when the other is at the end of the stroke, and there will be two curves according as the steam in A is released just before or just after the cut-off in C; the lower curve cor-

FIG. 4.

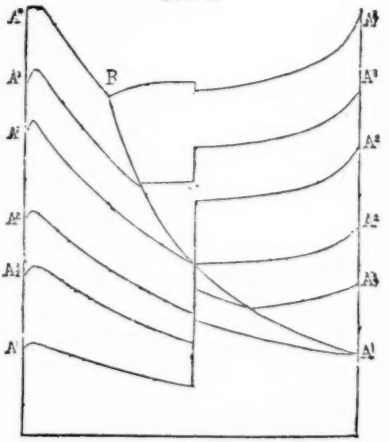


responds to the latter assumption, the upper to the former. In every diagram the volume of the receiver, or B, has been taken as $\frac{3A}{2}$, except that the dotted line in Figs. 2 and 4 illustrate the case when B = 5 A, and

show the effect induced by a very large receiver.

After the connection between the receiver and the large cylinder is closed, the pressure in the latter for the remaining part of the stroke will be the same as if the same total expansion had taken place in one cylinder. This will be readily seen by considering its final pressure, and tracing it backwards to the point of cut-off. The curve B A_1 will then depend simply on the total ratio of expansion. It will be noticed that increasing the size of the receiver makes the back pressure more uniform, and it is obvious that were the receiver infinite the curve would become a straight line. The mean back pressure is also somewhat less as the receiver is larger. With the same total

FIG. 5.

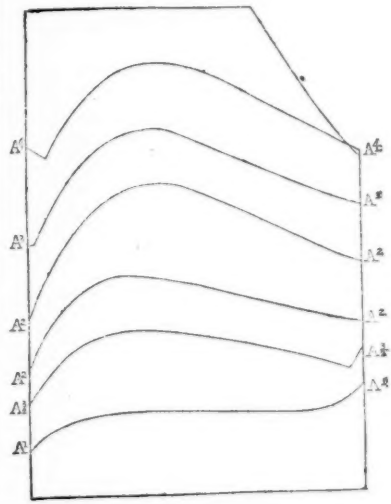


ratio of expansion, r, and size of receiver, the remaining elements which affect the diagram are the relative volumes of the cylinders, and the point of cut-off in C, the low-pressure cylinder; the latter of these two considerations is by far the more important.

When the horse-power required and the total ratio of expansion to be used are determined, the volume of C is also fixed, and will be that of a single engine with the same value of r. The small cylinder can have theoretically any size between C and $\frac{C}{r}$; the nearer the dimensions of the two cylinders, the greater of course will be the actual volume of A.

The volume of the receiver at any time includes not only the receiver proper, but also the portion of the two cylinders to which the steam has access at that time; it follows that the smaller A is, the smaller also is the volume of the receiver, and *vice*

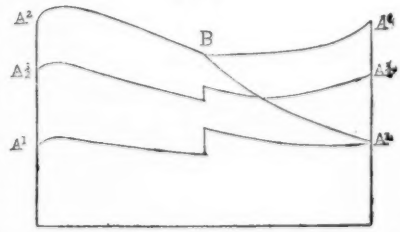
FIG. 6.



versa. So that the back pressure curves are less arched when $\frac{C}{A} = 4$, than when $\frac{C}{A} = 2$.

The same effect is induced by cutting off early in the large cylinder, and for the same reason, as this also curtails the space in the receiver. As might be expected, this irregularity is much more noticeable when $r = 6$ than when $r = 12$, for in the former case

FIG. 7.



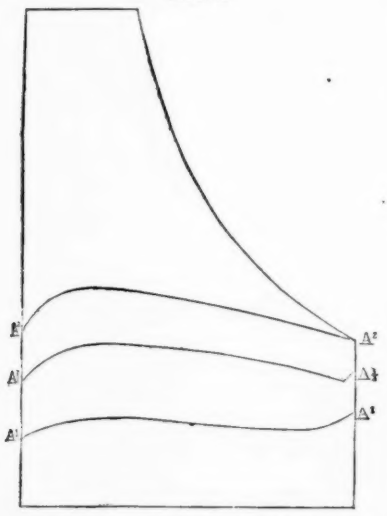
twice the amount of steam is admitted into the small cylinder, and in consequence the volume of the receiver is proportionately halved. This arched form of the back pressure curve would seem to be of some slight

advantage, as it lessens the forward pressure at that part of the stroke where the greatest bursting strain is thrown on the shaft.

The sudden rise in the middle of the low-pressure diagrams is due to the exhaustion of the steam from the small cylinder into the receiver at that part of the stroke. Owing to the gradual opening of the ports this rise would not of course be so marked in practice.

The amount of the rise will depend upon the difference between the final pressure in A and the pressure before exhaust in B, and this latter will depend mainly upon the cut-off in C. There will be one point of cut-off for every proportion of cylinders,

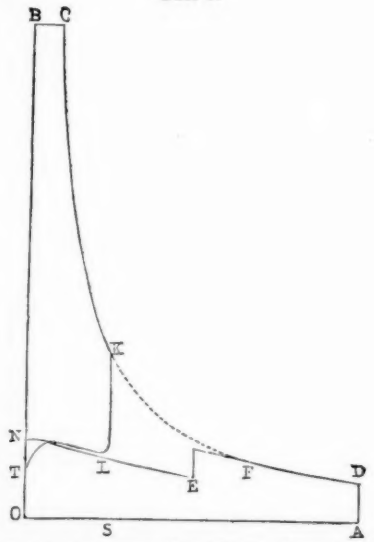
FIG. 8.



such that the release of the high-pressure steam will make no difference in the receiver pressure. This occurs very approximately when $q = \frac{C}{A}$. The pressure at the cut-off is then $\frac{P\,q}{r} = \frac{P\,C}{A\,r}$ = final pressure in A. For any greater value of q the final pressure in A will be less than that in the receiver at the same time; and on making the connection between the two, the steam in the receiver may be said to exhaust into the cylinder, instead of that in the cylinder into the receiver.

It has been already remarked that the mean back pressure depends mainly upon the value of q—that the longer the steam is admitted into the large cylinder the less will be the horse-power developed in it. So that by altering the value of q we are able to vary within very wide limits the proportion in which the work is distributed between the two cylinders. Perhaps the earliest cut-off useful in practice would be when $q = \frac{C}{A}$; the backward and forward pressures in A would then be equal at the end of the stroke; it will be seen hereafter that if q has any less value there is always a loss of work as the steam passes from one cylinder to the other, and that this loss may, under certain circumstances, attain very considerable proportions. The actual amount,

FIG. 9.



and also the proportion of work done in the two cylinders, will be seen most clearly by combining the high and low pressure diagrams. This can be readily effected in the following manner:—

In Fig. 9 let abscissæ measured along O A represent volumes of the cylinder swept through by the piston, and ordinates measured on O B the pressures at corresponding times. Let O A represent the volume of the large cylinder, which, as before stated, will be that of a simple engine developing the same power under the same total expansion. Then the hyperbola O B C D A will be the expansion curve of such steam in a simple engine working under the same

final and initial pressures. The area O B C D A will represent the work done in this engine, and will also represent the sum of the work done in the pair of compound cylinders, if there are no losses incurred in the passage of the steam from the high to the low pressure cylinder.

In other words, the combined horse-power of the compound engines can never be greater than that of the simple engine working under the same conditions; but may, and in practice always must, be less.

On O A take O S, such that $\frac{O\,A}{O\,S} = \frac{C}{A}$.

With O S to represent the stroke of the small cylinder, lay off the curve of back pressure T L, and with O A to represent the stroke of the large cylinder, lay off the curve N E F D of forward pressure in that cylinder. Although the actual stroke of each engine is assumed the same, the volumes swept through will be proportional to the abscissæ O S and O A. The forward pressure in A will be the hyperbolic curve C K, part of that due to the expansion in a simple engine; so also the final part F D of the forward pressure in C joins the same curve.

In Fig. (9) $\frac{C}{A} = 4$; $r = 12$; $q = 1\frac{1}{2}$

(10) $= 4$; $= 12$; $= 4$

(11) $= 4$; $= 6$; $= 1\frac{1}{2}$

(12) $= 4$; $= 6$; $= 4$.

The area T B C K L is the work done in A in each diagram.

The area N D A O represents the work done in C.

The line O A, from which the absolute pressures are calculated, must in practice be replaced by O′ A′, where O O′ represents the back pressure in C due to an imperfect vacuum.

(To be Continued.)

TRAIN-SPEEDS ON FUTURE TRUNK FREIGHT LINES—AN ANSWER TO SOME CRITICISMS.

By RUSSELL SAGE, Jr.

Written for Van Nostrand's Magazine.

The "Chicago Railroad Gazette" of May 3d, 1873, in its review and criticisms of my figures published in the May number of this Magazine, makes the remarkable mistake of assuming ultimate steam power of a locomotive, instead of economic adhesive weight on driving wheels, as the proper measure of the amount of work capable of being performed by it on a line of railway. The editor quotes coefficients of tractive resistance as 8^{146}, 8^{585}, 10^{239} lbs. per ton moved over a straight and level track at 5, 10, 20 miles per hour respectivly—values I will accept simply because he has used them in his calculations. Originating some very peculiar mechanics, he says *power=mass×velocity* (MV) and again that *engine-power=resistance at a given speed×velocity×train load;* acting upon this theory for a locomotive engine he continues, "so if we take Mr. Sage's train of 25 cars at 20 miles an hour, assuming the loaded cars to weigh 20 tons each, we have the

Engine-power $= 10^{2\cdot39} \times 20 \times 500 = 102{,}390$ lbs."

If this numerical product, which he terms pounds, means anything, it is that, to haul a train of 500 tons at 20 miles an hour over a straight and level track, he wants a locomotive of tractive or effective haulage power sufficient to lift 102,390 lbs. one mile in one hour—*i.e.*, mile-pounds per hour. Calling this the engine-power of a locomotive is original. Retaining his given train-load of 500 tons he finds

	At 20 miles.	At 10 miles.	At 5 miles.
Engine-power (!)	102,390 lbs.	42,925 lbs.	20,365 lbs.

Carrying his peculiar theory farther along I find

	At 1 mile.	At $\frac{1}{10}$ mile.	At $\frac{1}{100}$ mile.
Engine-power (!)	4,000 lbs.	400 lbs.	40 lbs.

still hauling 25 cars or 500 tons. Or, carrying it to a *reductio ad absurdum*, I find a locomotive of infinitely small engine-power actually hauling 500 tons every one of which is assumed to oppose at leat 8 lbs. resistance! On the abstract principle of virtual velocities these things are possible; but, inasmuch as the locomotive is supposed to remain with and attached to its train, I am at a loss to determine how and where

he intended to place his engine-power so that, for instance, 40 lbs. would lift 4,000 lbs. for $\frac{1}{100}$ of a mile in one hour.

Calling his 102,300 lbs. a fixed engine-power (!) he found equivalent trains for this power on a straight and level track to be

	At 20 miles.	At 10 miles.	At 5 miles.
Number of cars....	25	$59\frac{63}{100}$	125

and then dogmatically and contemptuously annihilated my figures. Retaining his fixed engine-power and following his theory, I find equivalent trains to be

	At 1 mile.	At $\frac{1}{10}$ mile.	At $\frac{1}{100}$ mile.
Number of cars....	640	6,400	64,000

or, carrying the process *ad infinitum*, I find a locomotive of a fixed or limited power actually hauling an infinite number of cars every ton of which is granted to oppose at least 8 lbs. resistance! and this, too, a mathematically correct sequence from his wondrous formula. While as an abstract proposition Archimedes might lift a world, as a practical fact it is absurd and of no value. So too, while his locomotive of a given or fixed power that will haul just 25 cars or 500 tons at 20 miles an hour, may haul $59\frac{63}{100}$ cars at 10 miles an hour, as a practical fact it is ridiculous and of no value when we remember that his same locomotive must continue to run at 20, while its train is running at 10 miles an hour!

Discarding mechanics in a simple arithmetical problem, and accepting his coefficients, I find

	At 20 miles.	At 10 miles.	At 5 miles.
Tractive resistance..	$5,119\frac{5}{100}$ lbs.	$4,292\frac{5}{100}$ lbs.	4,073 lbs.

for a train of 25 cars or 500 tons over a straight and level track. These numbers measure also the pounds of adhesion there must be between rails and driving-wheels to just overcome the respective train resistances. Since the tractive resistance of his equivalent (!) train of $59\frac{63}{100}$ cars at 10 miles is $10,238\frac{5}{100}$ lbs, and of his equivalent (!) train of 125 cars at 5 miles is 20,365 lbs., assuming as he has that the given locomotive will just haul 25 cars at 20 miles an hour, then if he concludes to keep up attachment between locomotive and train he must provide double the adhesion for the train at 10, and quadruple for the train at 5 miles an hour, or in other words, double or quadruple the weight of the given engine for a straight and level track. The tractive resistance of his $59\frac{63}{100}$ cars for a "dead pull" on a 35 ft. grade would be 28,000 lbs., requiring at least that much adhesion between rails and driving-wheels, or an engine weighing from 5 to 10 times that amount depending upon rail and weather. Under the same conditions his train of 125 cars or 2,500 tons would require at least 57,700 lbs. adhesion or an engine weighing from 5 to 10 times that amount. And under the same conditions my train of 25 cars or 500 tons would require an adhesion of at least 12,500 lbs., neither calculation taking any account of margins or of resistance from tender and engine. Truly, the equivalent locomotives, in which he must put his so-called fixed engine-power to just haul his equivalent (!) trains, are weighty matters in the light of present experience!

Having assisted the gentleman out of a quagmire, and given his locomotives double and quadruple the weight of the first, so that his engine or tractive power will have something to pull at in moving his equivalent (!) trains of $59\frac{63}{100}$ and 125 cars, let us see how he may develop his so-called fixed engine-power, now that he has consented for practical reasons to run his locomotives attached to their respective trains by the usual or ordinary direct connections. There is nothing truer than this: If a given power—measured by a numerical product you may term horse-powers or foot-pounds per minute, or mile-pounds per hour—will raise 1 ton 1 ft. in 1 min., then will it raise 2 tons $\frac{1}{2}$ ft. in 1 min. all in vacuo. Introducing atmospheric resistance, we may say that if a power of 102,390 will pull 500 tons 20 miles in 1 hour, then will it pull $1,192\frac{6}{10}$ tons 10 miles in 1 hour, and 2,500 tons 5 miles in 1 hour; but in this case our power travels with the trains and is exerted $\frac{1}{2}$ and $\frac{1}{4}$ as fast as in the locomotive at 20 miles; and hence to accomplish equivalent work, bearing in mind that power = force $\times$ effective space or force $\times$ lever arm, we must either double and quadruple force since it moves through $\frac{1}{2}$ and $\frac{1}{4}$ the same space in the same time, or must retain force constant and make effective space or lever arm double and quadruple that in the first instance. Hence in his equivalent weighty engines—which no one will tolerate in any way—he

must also do one of four things:—*First*, keeping the lever arm and steam pressure constant, he must double and quadruple the area of his cylinders. *Second*, keeping lever arm and area of cylinders constant, he must double and quadruple steam pressure in boiler and on pistons. *Third*, keeping steam pressure or force constant, he must double and quadruple length of stroke. Or, *fourth*, keeping steam pressure and stroke constant, he must reduce diameter of driving-wheels to ½ and ¼. None of these or any combination of them are practicable or reasonable alterations in any locomotive of to-day just capable of hauling 500 tons at 20 miles an hour over average roads and grades. We dismiss his locomotives for their intolerable weight, and cry "bosh" at his fixed engine-power.

Calling $5{,}119\frac{5}{10}$ lbs. a fixed train resistance, I find equivalent trains or trains opposing to traction that constant resistance, to be

	At 20 miles.	At 10 miles.	At 5 miles.
Number of cars	25	$29\frac{8}{16}$	$31\frac{4}{10}$

for a straight and level track. These figures speak volumes when compared with his terrific 25, $59\frac{6}{10}\frac{3}{0}$ and 125 cars to be hauled by one engine around curves and over hills as equivalent trains. And pseudo doctors *will* practice medicine and give magisterial opinions! Introducing gravity—a matter my friend thought perhaps trivial—he will find that the train resistance of 25 cars at 20 miles for a "dead pull" on a 35 ft. gradient, is equal to that of not quite 27 cars at 10 miles; so that a locomotive, which will haul just 25 cars over that grade at 20 miles, will haul not quite 27 cars at 10 miles, and no more—not one pound. The determination of equivalent trains for a locomotive with a fixed engine-power at different speeds, without any thought as to how this constant power is to be developed at the slower speeds, may be a fair arithmetical exercise for a school-boy, but men who have locomotives to build and trains to run might call it trash. The locomotive of weight sufficient to give a proper margin of adhesion for $59\frac{6}{0}^{3}$ cars, or $1192\frac{6}{10}$ tons at 10 miles, and constructed so as to develop at 10 miles the same power as that exerted by a locomotive hauling 25 cars or 500 tons at 20 miles, would, if built, positively haul those same $59\frac{6}{10}\frac{3}{0}$ cars at 20 miles by burning relatively more coal and evaporating relatively more water.

So much for the little there is in this matter of equivalent trains for different speeds, and now for a practical necessity that eliminates this little from my equation. I assert that for any average 100 miles of road I shall want the same sized locomotive—whence the same tractive and engine-power—whether my train-speed be 10 or 20 miles an hour. The capacity or power of an engine, expressed in cars or tons hauled over 100 miles of average road, is the number of cars or tons it can haul over ruling gradients at same speed, whether the total 100 miles is made in 5 or 10 hours.

My friend seems to have confounded average speed with an impracticable uniform speed for a given locomotive, maximum load and gradients. "There are four things to be adapted to each other: the greatest load of train, the least speed of conveyance in ascending declivities, the description of engine, and the ruling gradients." (Rankine.) Having of necessity weight and power sufficient to haul my maximum train over ruling and other grades at some reasonable speed, I purpose to utilize that weight and power in making greater average speeds and effecting economies claimed for a maximum tonnage. The resistances encountered and overcome by a locomotive hauling 25 cars or any train at 8 miles an hour over a 16½ ft. gradient, are greater than those encountered and overcome in hauling the same load over a level track at 30 miles an hour; and the resistances overcome on a 26 or 35 gradient at 8 miles, are greater than those encountered on a level track at 42 or 50 miles an hour. Resistances to traction due to speed *per se* are a mere bagatelle compared with those due to gravity—speaking, of course, within reasonable limits of speeds for freight service. "The railway manager who works his trains at a speed at which but from 20 to 35 per cent. of his power is utilized, may not only make up his mind to a heavy loss in money as well as in power, but may also look forward to an early 'smash.'" (Colburn.) The speed at which a locomotive may run when exerting a certain effort—as hauling a given train—depends upon the quantity of steam, at the pressure necessary to maintain that effort, its boiler is capable of producing in a given time, and this depends upon the quantity of coal that can

be burned and water evaporated in the given time; so that increased speed is synonymous with increased consumption of coal, and increased power for greater speed is simply more steam. Certain it is that mere steam power is cheap, and a small element in railway expenditures compared with those it may be used to lessen; equally certain is it that the power expended by 1 locomotive in hauling 25 cars over 200 miles of average road in 10 hours, is no more than the power expended by 2 locomotives doing collectively the same work in the same time at half the average speed; and for the economies effected by increased speed for a maximum tonnage, I can say no more than has been already said in my original statement.

"A prominent railway officer in the East," who says that "we grope in the dark in many things relating to railway economy, and must search for the truth if we would find it," communicates to "The Chicago Railway Review" (May 17) an article on "Train Speeds and Rolling Stock," in which he makes some wonderfully impracticable propositions I will briefly notice.

He proposes to put 25 tons of freight on to a car instead of 10 as now, thus reducing the number of cars per tons moved and the proportion between live and dead loads. A car that will safely carry 10 tons will not safely carry 25 tons, and there is no escaping the fact that his car must be proportionately stronger. A car that will store away 10 tons will not store away 25 tons, and there is no escaping the fact that his car must be proportionately more bulky for average freight, excepting of course the metals and not excepting his cited and only example of grain. His proposition emphatically demands the rebuilding of the entire rolling-stock of the country, and in a style perfectly inadmissible. Breadth cannot be increased without opening the question of gauges; height cannot be increased without an alteration in tunnels, bridges, and crossings, and a raising of the centre of gravity which is already too high for steady motion and economic traction; and if length is increased I am at a loss to determine just how reasonably and surely the necessary increase in strength and rigidity of car body is to be obtained. He assumes that, to carry 25 tons or $2\frac{1}{2}$ times the present maximum load, his car need not and will not weigh any more than our present car, viz., 10 tons. This is wonderful! Accepting this statement as true, then his loaded car will weigh 35 tons or $4\frac{3}{8}$ tons to each wheel.

The greatest load permitted on any car-wheel to-day is $2\frac{1}{2}$ tons, which is not reached by 1 car out of 100 in average service, and even this pounds our rails too much. Is it possible that weight on the wheels is of no consequence, and that we have all been dreaming? He says that $4\frac{3}{8}$ tons is less than the weight carried on driving-wheels; true, but not much, and driving-wheels, my friend, are larger than car-wheels. Positively, a 5 ft. driver carrying even 6 tons will not wear and abrade itself and rail as much as a 33 in. car-wheel carrying $4\frac{3}{8}$ tons, and besides, with such a load the car-wheel itself must suffer badly. Is it possible that the gentleman does not know why we are forced to carry such loads on driving-wheels and how gladly we would be relieved from the burden? Taking his train of 15 cars, for every 3 driving-wheels carrying from 5 to 6 tons each, he would have 60 car-wheels carrying $4\frac{3}{8}$ tons each! I would prefer not to buy rails and car-wheels or build roads for him to pound up so ruthlessly. Without his permission I am forced to put 8 more wheels under his imaginary car and guess it to weigh not far from 16 tons, which with his 25 tons of freight give 41 tons gross or $2\frac{9}{16}$ tons per car-wheel. Instead of rebuilding our whole rolling-stock, on a false plan theoretically and practically, why not for economical reasons make use of the several hundred thousand cars already built? And in the attempted solution of any practical problem is it not wise and well to confine ourselves to existing circumstances? That our present cars, to carry 25 instead of 10 tons of grain, flour, lumber, merchandise, live-stock, provisions, and general freight, must be rebuilt, is a fact too evident for even a "prominent railway official in the East" to disprove; and the assumptions that such a car would weigh no more than our present car, and that any sand railway man would knowingly put $4\frac{3}{8}$ tons on every car-wheel where he now grumbles terribly to find $2\frac{1}{2}$, are too much even for the Egyptian darkness through which some men grope. Granting the gentleman all he claims as to weight of cars, allowing him to put $4\frac{3}{8}$ tons on each wheel and 15 of his cars in a train, and we have his own table copied as follows:

Comparative statement.

	Mr. Sage's plan.		As proposed.
	Speed per hour.		Speed per hour.
	10 miles.	20 miles.	10 miles.
Number of trains in use	72	52	48
Freight cars in use	1,800	1,300	720
Locomotives in use	80	40	75
Conductors required	80	40	55
Enginemen required	80	40	55
Firemen required	80	40	50
Brakesmen required	160	80	110
Number of trains on road at one time	40	20	27
Number of trains at both termini at once	32	32	21
Distance between trains—minutes	30	30	45

His deliberate misquoting of my figures is in bad taste, and I have taken the liberty to correct them. Each one of the three plans above indicated will insure the delivery of 12,000 tons at each terminus every 24 hours, if his cars are fully loaded to his limit of 25 tons each, and if my cars are fully loaded to 10 tons each. I will not admit that a car for a 4 ft. 8½ in. gauge to carry 2½ times our present maximum load can be built at less weight than 16 tons, and hence his 15 loaded cars will weigh $41 \times 15 = 615$ tons gross. I understand that he is a Superintendent of some railway in Pennsylvania, and if his locomotives will haul 615 tons over his road at the average speed of 10 miles an hour on his plan, then giving his locomotive for his comparison 613 tons and his locomotive for my comparison 500 tons is too boyish; and if any locomotive will haul 615 tons or 30¾ of our present cars fully loaded over an average 100 miles of road at the average speed of 10 miles an hour, then will it haul the same train over the same road at an average speed of 20 miles; and for a maximum tonnage, effect the economies I have claimed in engines, cars, men, etc. Again, any engine that will haul 500 tons over average and ruling gradients at any speed—and a good engine it is—must, to pull 615 tons over that same road at any average speed, be increased in weight and power in the proportion 615 to 500. And finally, if our cars must be rebuilt, then must they be built to *safely* carry his 25 tons; when so built I dare run them at an average rate of 20 miles, when the question of maximum tonnage is upon us, and my same problem will remain of the same kind, but not perhaps of the same degree. The gentleman has not caught the meaning of my figures at all. It is not how much tonnage can we possibly haul over a given road in a given time, for that depends wholly upon the number and weight of the trains we can possibly move in the given time; but, having settled that point, it is, run those trains not at 8 or 10 miles an hour, but at some greater speed, and effect the economies fully considered in my original statement. Certainly for this maximum tonnage there must be some limiting train-speed most economical, *all* things considered, and not wear of rails alone, and whether it be 20 miles or more or less I, for one, don't believe it to be 10 miles. Or to give my problem immediate application, it may be stated thus: For a given road with a given limited rolling-stock pressed with business, how many loaded trains can possibly be made up and moved in a given time? This each superintendent must solve for himself according to his road and equipment.

Train resistances to traction are variously made up, and as the average result of extended experiments different authorities have given us different formulas, as follows:

$$\text{Resistance} = 8 + \frac{V^2}{171} = \text{lbs. per ton moved (Gooch).}$$

$$\text{“} = 6 + \frac{V^2}{240} = \text{“ “ “ (Clark).}$$

$$\text{“} = 6 + \frac{6V - 60}{20} = \text{“ “ “ (Gooch).}$$

for a straight and level track, all of which vary widely. The first formula was constructed by Gooch and is undoubtedly the one adopted by the “Gazette.” The constants 8, 6 are assumed through average trials to represent the total effects of all the mechanical frictions, and which, while absolutely independent of speed, vary largely with conditions of track and rolling-stock. The assumptions of the “Gazette” and Supt. W. that our present tracks are perfect and tractive-resistance now a minimum, imply a doctrine that if acted upon some years ago would have found us to-day riding in ox-carts over corduroy roads. When perfection in a railroad is reached then will we be operating railroads through ethereal space, but not, I trust, with a fixed

engine-power for all speeds or with $4\frac{3}{4}$ tons on a car-wheel. The second parts, as $\frac{V^2}{176}$, are supposed to measure nearly the effects of atmospheric resistance, which, while it varies absolutely with speed, is for ordinary velocities small compared with the constant frictions, and inappreciable compared with gravity. To be exact, the terms $\frac{V^2}{171}$, $\frac{V^2}{240}$, etc., are supposed or intended to measure the combined effects of atmospheric resistance and of concussion; the former depends not so much upon the weight of train as upon its length and frontage area, and the two effects combined equal a variable quantity that may for comparisons be approximately represented by these terms. The resistance of gravity is additional, and may be measured closely by 2,240 lbs. divided by what I might term the average of the gradient—*i. e.* if gradient be 1 in 100 or 1 in 150, by 100 or 150, etc. Resistances due to curvature have been closely studied, and are measured by those of an equivalent grade. Now a 4 deg. curve on a 35 ft. gradient is not a wonderful occurrence, and a speed of 8 miles an hour not unreasonable going over such places on any average road. The speed may be assumed at 5 miles or 3 miles without any measurable effect upon the comparison I am about to make. Assuming that a 4 deg. curve for average alignment is equivalent in resistance to that of an 8 ft. gradient on a straight line, the total resistance of curve and gravity would be that due to a 43 ft. gradient (or 1 in 123 nearly)—*i. e.*—$\frac{2240}{123} = 18\frac{2}{10}$ lbs. per train ton; calling atmospheric resistance nothing and that due to frictions 8, we have, dropping fractions, 26 lbs. per train ton resistance to traction; and not considering margins, tender or engine itself, we must have at least 26 lbs. per train ton adhesion on driving wheels. As a positive fact, there is for a given locomotive only one maximum load or train, for an average road, no matter whether our average speed be 5, 10, or 20 miles; and the silly equivalent trains of the "Gazette" tyro, based on his utterly impossible fixed engine power for a locomotive at all speeds, are "trash." Let us figure the total resistances of his equivalent(!) trains, and the adhesion he must at least have for a "dead pull" over our grade and curve.

25 cars. $-500 \times 26 = 13{,}000$ lbs. resistance and adhesion.

60 " $-1200 \times 26 = 31{,}200$ lbs. resistance and adhesion.

125 " $2500 \times 26 = 65{,}000$ lbs. resistance and adhesion.

Not only must the weights of his engine vary as 13 : 31 : 65, but his *power must vary also with these numbers.* And these are equivalent trains for a fixed engine-power! Truly, one would think another Rip Van Winkle had awakened surfeited with the abstract principle of virtual velocities! and believing the world to be a vast level plain resting upon the back of some huge "What-is-it!"

For a comparative statement of the resistances to traction from gravity and atmospheric resistance, let us assume as correct

$$\text{Resistance} = 8 + \frac{V^2}{171} + \frac{2240}{L} = \text{lbs. per train ton.}$$

in which V= train speed and L= radius to which 1 is the sine of the angle of inclination, or, as I have expressed it, the leverage of the gradient. Assuming a speed of 8 miles an hour over gradients, we have

$$\text{Resistance} = 8 + \frac{64}{171} + \frac{2240}{L} = \text{lbs. per ton.}$$

and since this resistance must be equal to that of the same train over a straight and level track at an unknown speed V, we have

$$8 + \frac{64}{171} + \frac{2240}{L} = 8 + \frac{V^2}{171}$$

whence

$$V^2 = 64 + \frac{383040}{L}$$

Making various suppositions as to L we find equivalent values for V—whence this table, which may be of interest.

Train resistances are equal for		
An eight mile per hour speed.		Over a level and straight track at a speed of, miles per hour.
Over a gradient of—	Ft. per mile.	
1 in 1000	5.28	21.1
1 in 900	5 87	22 1
1 in 800	6.60	23.3
1 in 700	7.54	24.7
1 in 600	8.80	26 5
1 in 500	10 56	28 8
1 in 400	13 20	32 0
1 in 300	17.60	36 6
1 in 200	26.40	44 5
1 in 150	35.20	51.1
1 in 100	52.80	62.4
1 in 75	70.40	72.0
1 in 71.9	73.42	73.42

That is, a locomotive hauling a train of 500 tons, or of any other weight, over a $26\frac{4}{10}$ gradient at 8 miles an hour, will encounter and overcome a train resistance equal to that of the same train over a level track at $44\frac{5}{10}$ miles an hour; but, while the effective steam pressure on pistons will in each case be theoretically the same, the steam at this constant pressure must be delivered faster in the proportion of $44\frac{5}{10}$: 8, and whence increased power, as nominally measured.

When we remember that this increased steam power for increased velocity is simply the burning of more coal and evaporating more water in a given time, then, keeping within reasonable limits of boiler capacity, I urge greater average speeds (within sound practical limits) and less equipment and men for any maximum tonnage; and unless I err greatly, one engine hauling a train at an average speed of 20 miles over an average road for ten hours will consume less coal than two engines doing collectively the same work in the same time. I have endeavored not to burden my subject of train speeds with that of maximum tonnage, a subject by itself, and which, as before stated, depends wholly upon the greatest number and weight of trains that can be moved within a given time, but have started my problem at the point where maximum tonnage has been settled by practicable limits to weight and power of locomotives, and by the character of road for grades and alignment. I cannot resist making these figures: a locomotive of weight and power sufficient to haul at a "dead pull" 25 loaded cars over a 35-ft. gradient, and around a 4-deg. curve, will, so far as its tractive power and the resistances to be overcome are concerned, haul $25 \times \frac{26}{10^{0.39}} = 63\frac{5}{10}$ loaded cars over a straight and level track at 20 miles an hour; and will positively do it if its boiler capacity is such as to deliver steam at the same pressure proportionately faster. If ruling gradients be reduced so that our given engines will each haul an additional five loaded cars, then for half-hourly trains will our same engines and trainmen haul every twenty-four hours $24 \times 2 \times 5 = 240$ additional loaded cars each way, or 87,600 additional loaded cars each way every year. The time is coming when Directors themselves will insist upon approximately level and perfect road-beds for trunk lines; and I urge humbly that all these half-hourly trains be not run at 8 or 10 miles an hour. It would be too costly, and expenses, interest, salaries, equipment, etc., would eat up earnings.

TRACTION ON CANALS.

From "Engineering."

We have already described the locomotive designed by M. J. Larmanjat, which, with several modifications, has been adopted by Mr. F. H. Trevithick for working tramways in Portugal. As our readers know, a central single or double rail is employed, upon which run two wheels, placed at the front and back of the machine, and along the line of its axis; besides these there are two side wheels in the middle of the vehicle which rest upon the ordinary road surface. These last are the driving wheels, while the former are the guiding wheels. Arrangements are made to adjust at will the distribution of weight between the driving and guiding wheels. M. Larmanjat considered that one valuable application of his system lay in employing it for the traction of canal boats, and the experiences he has gained in this direction are of sufficient interest to justify our placing them before our readers, although we by no means share Mr. Larmanjat's views as to the applicability of his system for towage purposes. On the 28th June, 1871, he obtained from the Minister of Public Works authority to make experiments in this direction on the Canal of Bourgogne. The results obtained appearing satisfactory, he made application for permission to extend the system upon the same canal, between Laroche and St. Jean-de-Losnes. This application was accompanied by a memoir, from which we may quote the principal points.

The question of interior navigation is at present one of vital moment in France. This was clearly explained at the last presidential address delivered at the Society of Civil Engineers in Paris, a *résumé* of which we recently published. In France, river and canal transport has already the

advantage of cheapness; if the regularity and rapidity which it wants, could be imparted, means would be provided by which internal channels of navigation could enter into successful competition with railways.

The water route which connects the Channel with the Mediterranean, is divided into three sections, the first and last of which possess the advantage we have just alluded to. Steam-towage is established between Le Havre and Montereau, and it should be extended to Laroche; that is to the embouchure of the Canal of Bourgogne. From Laroche to St. Jean-de-Losnes, the boats are hauled by horses on the Bourgogne Canal. Lastly the journey to the Mediterranean by the Saône, the Rhône, and the St. Louis Canal, is completed by steamboats.

To increase the speed of haulage on the Bourgogne Canal, various systems have been proposed, steam tugs, hauling in a sunken chain, and lastly towage by locomotives on the canal banks. M. Larmanjat examines in his memorandum these different projects, and concludes by rejecting, and, naturally, by suggesting the substitution of his own system. The boats traversing the Canal Bourgogne measure about 150 tons, and the trials made by M. Larmanjat, to which we have already alluded, showed that a locomotive weighing 4 tons could haul one of these boats at a good working speed.

The single rail proposed by M. Larmanjat weighed about 15 lbs. per yard, and the engine presents the ordinary features of his system. The side wheels are furnished with rubber tyres. The adjusting mechanism of which we have spoken, permits the weight to be thrown either on the guiding, or on the driving wheels, according as to whether the boat is empty or full. With this arrangement such a machine, weighing 4 tons, will haul at the rate of 2½ to 3 miles an hour, a boat loaded with 150 or 160 tons. Each engine will haul a single boat and would travel until it met another, when the two would exchange loads and return towards their respective points of departure. Thanks to this arrangement one line would suffice for accommodating the whole traffic of the canal. The mean distance between these relays would be 15 miles, so that with 10 relays the whole canal, which is 150 miles long, would be worked.

Rapidity and regularity of transport being the essential characteristics of steam traction, M. Larmanjat endeavored to place himself in these points in the best possible condition. Passing through the locks cannot, of course, be avoided, but the mean duration of a lockage is only 5 or 6 min., and this time could be usefully employed in tending the engines. Standing before the locks, when other boats are within them, would be a cause of delay of considerable importance in respect to the slow-speed boats hauled by men or horses. Then M. Larmanjat would claim the right of "*trématage*," that is to say, the privilege of pasing his boats first through the locks, when they should be within 500 metres. This privilege, indispensable for steam-hauled boats, would occasion only very small inconvenience to those vessels towed by hand or horses. Lastly he requested that the rail should be placed on the actual towing path, because the width beneath all the bridges is sufficient for allowing the engine to pass.

We may now see what, according to M. Larmanjat, would be the practical consequences of the application of his system. The 60 boats which traverse the Bourgogne Canal, on an average with a mean journey of 30 miles, make altogether about 1,800 miles per day, supposing that they travel through the 24 hours. Steam towage gives a double speed to the horse towage, and fourfold that of haulage by hand. The adoption of his system should, therefore, double the traffic; but admitting that the traffic should remain the same, as the speed is doubled, a daily circulation of 30 boats would be sufficient, which would give a to-and-fro journey for each beat of 10 miles, the length of the canal being 150 miles. Thirty engines in use and 10 in reserve, would be ample for the service. Under these conditions an economy would be realized in the *personnel* of the boats, and one-third more freight could be transported with the same number of vessels. Moreover, M. Larmanjat proposes a tariff very closely approximating to that of horse haulage, despite the greater speed he proposes to attain.

We have stated that the proposition made by M. Larmanjat was very favorably entertained, and he obtained a concession for 40 years for the working of his system on the Bourgogne Canal, between Laroche and St. Jean-de-Losnes. The conditions of working are determined by an agreement, dated January 13, 1873. According to this agree-

ment, the speed attained must not exceed 5 miles an hour with empty and 3⅛ miles per hour with full boats. The right of way for lockage is accorded. The maintenance of the towing path will not be charged to M. Larmanjat, unless it is shown that his system causes special injury.

The towage tariff is established on a scale decreasing with the distance, and is divided into two classes. The boats on the Bourgogne Canal weighing from 30 to 35 tons, and carrying a useful load of 150 tons, it is easy from the tariff to ascertain the charge of transport for an empty and for a loaded boat. The financial organization of this canal towage scheme has been commenced by the Crédit Mobilier, and it is anticipated that the rails will be laid in four or five months, whilst the working will be commenced gradually so soon as sufficient length of line is complete.

M. Larmanjat gives the results of some experiments recently made on the Bourgogne Canal by a Commission of Engineers of the Ponts et Chaussées. The engine was driven at varying speeds, and the amount of traction was ascertained under the different conditions as follows:

Speed per hour.	Tractive force.
Barge loaded 1¼ miles.	440 lbs.
" 3⅛ "	1100 " (about 6 6 lbs. per ton.)
Barge empty 6¼ "	440 "

The average tractive power of a horse is estimated at about 143 lbs. on the draw bar.

These trials went to show that the maximum speeds that can be attained without inconvenience are 3⅛ miles, with a loaded, and 6¼ miles with an empty barge. The official conditions impose, as we have seen, a maximum speed of five miles per hour upon empty boats. But after the results obtained at the above-named experiments, it is probable that a higher speed will be petitioned for. As to consumption of fuel, it was found on an average equal to 35 lbs. per mile. This figure is a high one, but probably cannot be reduced, on account of the various losses of power inseparable from the system.

We have drawn attention to this effort for developing the useful carrying capacity of canals, partly to indicate one of the directions which industrial enterprise is taking in France, and partly because a practical step in this direction, even though it be a useless one, is worthy of being placed on record. That the system of M. Larmanjat, or, indeed, that any system of steam towing from the canal bank can be made commercially successful, is almost, if not quite out of the question. Many experiments have been made in this matter, and in all cases without practical success; and certainly where light traction engines, which required no adaptation of the towing path, have failed, how much more certainly will failure attend a system which requires that a railway shall be laid down and maintained, especially when it is remembered that the same course is open to the common traffic of the canal bank; moreover, the practical difficulties in the way of working the system appear too great to admit of its meeting even with tolerable success.

A NEW AND IMPROVED SYSTEM OF WIRE ROPE TRAMWAY.*

From the "Mining Journal."

This system of tramway has been invented by Herr Hermann Müller, the director of Herr Sijl's engineering works at Vienna. The object of the invention is the erection of a cheap, expeditious, and effective mode of transport, suitable for districts where the traffic would not pay for erecting a railroad on the usual plan. In this system the cars, or other vehicles, are carried on two parallel endless wire ropes, passing at the terminal points over large driving and returning pulleys and being supported and guided at certain distances by smaller pulleys. These guiding pulleys are fixed to, and carried by, vertical posts of wood or iron, carried to any reasonable height. The distance between these supports depends upon the nature of the ground as well as upon the weight to be carried, but spans of 300 and 400 ft. are quite practicable. In many instances advantage may be taken of trees, or rocks, which may lie in the line of route. The motor, which may be a steam engine or water-wheel, only acts at one end of the line. The large pulleys at the driving end are both keyed on to one shaft, and are set in motion by the motor. These driving wheels, by the aid of the endless running

*Abstract of a Paper read before the Iron and Steel Institute, by Henry Martin Morrison, M. E.

ropes, communicate motion to the large pulleys at the returning end of the line, which pulleys are separately bedded, and run independent of each other, each having a tightening apparatus to prevent any unequal stretching of the ropes. These ropes also transfer the motion to the guide rollers. Any load to be transported, and consisting of vehicles, cars, trams, baskets, balks of timber, columns of iron, etc . etc., are made to rest upon the ropes with four claws or notches, in order to prevent slip and oscillation, and to enable them to follow the movement of the ropes while passing over the guide rollers. While two of the claws simultaneously set free the ropes, the two other claws keep the load upon the rope by friction. A system of disengaging claws attached to the tubs, and first used, was found expensive and complicated, and although retained as part of the patent, has now been superseded. A more simple method is now adopted, by which the claws are arranged to fall clear of the tubs, when not resting upon the ropes. The large driving and returning pulleys are lined with wood, so as to increase the grip of the ropes, and avoid the wear consequent upon the ropes being driven on iron beds. The average diameter of the driving pulleys is 10 ft, unless a very high rate of speed is required, when they may be increased according to the requirements. It is not necessary that the pulleys and ropes be driven vertically, as, when the empty cars weigh over 5 cwt., the driving pulleys can be placed nearly horizontal, so that both ropes run parallel and next to each other in one direction, and the return ropes are placed in the same plane at the side of each other. It is not necessary that the terminal stations should be in the same plane, but any inclination may be given to the ropes up to 1 in 6, which may be worked with perfect ease. The wire ropes are four times the length of the distance to be traversed, and must be of the best material and workmanship, and most carefully laid. Steel wire rope is strongly recommended, as being better able to withstand the wear and tear consequent upon the necessary friction. Messrs. Scott are preparing to manufacture a special class of rope for this purpose, tempered and annealed by a special process, and having their own wire-drawing mill on the premises. Every care will be taken that all wires in the ropes will be of uniform temper. The carrying power of these lines range from 500 tons to 1,500 tons per day. Sharp curves may be passed by placing the motor at that point where the line is required to be deviated, as the shaft of the driving pulleys may be so placed, that the rope-way will form an obtuse angle. An arrangement of this kind, which is designated the coupled "traject" system, is most suitable for long lines, because by dividing the line into sections, the weight of, and strain upon the ropes are very considerably diminished. The cars pass the junction without manual help, or without stopping, this being effected on the upper line of ropes by the momentum of the running car, and on the lower line by giving the rails the necessary inclination. At each end of the line a series of wood work, called "ramparts," are placed, to receive the cars from the running ropes, and also to enable the trams or cars to run on to the ropes without manual help. The cost of these lines average from £1,000 to £1,500 per mile, but the difficulties to be overcome, and weight to be carried, tend very considerably to diminish or increase the cost. The advantages of this system may be briefly stated as follows:—1. It can act as a feeder or as a means of communication between narrow-gauge railways, whose termini are intercepted by precipices, valleys, water, etc. 2. It avoids the expense of cuttings, embankments, bridges, etc. 3. Lines can be constructed as cheaply and efficiently in mountain districts as on plains. 4. They occupy scarcely any land, and may pass over rivers, houses, trees, etc. 5. They are not affected by flood or snow, and can readily be moved from place to place. 6. It can be employed in the carriage of coal, ironstone, and minerals of all kinds, having this advantage over other systems, that the minerals need not be unloaded and reloaded, but taken away direct from pit or level's mouth. 7. It is the most effective system for the carriage of slates, timber, beet-root, sugar, rice, coffee, cotton, and all kinds of plantation produce. 8. As passenger lines they offer a cheap and effective system of transport, having been used for that purpose. 9. It is most valuable as an accompaniment of an invading army. 10. Inundated land and broad lakes can also be passed over, and when the depth of the latter prevents the fixing of supports in the bottom, they can be fastened to anchored flats, with spans of 400 ft. between each flat.

ON AUXILIARY POWER FOR OCEAN NAVIGATION.*

From "Iron."

Many methods have been introduced for applying auxiliary power to sailing vessels, both before and since the introduction of steam power. The lifting screw, with the banjo frame, is one which, no doubt, has been successful; still there are objections to this method, as well as to the ordinary feathering screw, which I propose to remedy, and will, therefore, proceed at once to explain my method, which is, to construct screw-propellers with the novel feature of folding blades; that is to say, the blades are jointed, or hinged to the boss, or its equivalent, in such a manner that they can be folded into a fore-and-aft position; and without impairing the steering qualities of the ship, offer little or no resistance to her progress through the water when under canvas.

The system of feathering the screw accomplishes this to some extent; but owing to the twist in the blades that is essential to form a perfect screw, it must necessarily present some amount of resistance and cannot be rendered entirely neutral. It is obvious that the ability to fold the blades aft, so as to form a continuation of the vessel's lines, and give the water free access to the rudder, must secure to this method a great advantage over any plan of feathering, which only partly effects these objects, while folding the screw accomplishes this effectually. For vessels of war, especially twin-screw gun-boats, the invention will afford great advantages in sailing economy of fuel, and protection when in action. Merhant ships can be fitted at trifling expense, a small aperture at the after-part of the vessel for the screw to work in being all that is necessary, thereby obviating the necessity of lifting the screw on deck.

The folding screw will afford the long sought for advantages of a motive power in case of calms, and in steaming into or out of port, with the additional advantages that its power and form as a screw can be rendered neutral at will. The joints and couplings are simple, and not likely to get out of order, or weed up. Many arrangements of mechanism can be applied for folding the blades; but in practice, I prefer to carry a shaft, which I call the adjusting rod, through the driving shaft, and by a screw thread are made to hold the inner end of the same with toothed projections on the inner ends of the blades, by coupling links or by other means, the blades expanded when the shaft is pushed outwards, and folded when it is drawn inwards; when the blades are expanded they are held firm in position by being screwed hard up against a stop, and when folded they are secure, by bearing on each side of the rudder-post. When the propeller is being driven by the engine, there is no strain on the adjusting rod, as the strain is taken on the boss, and the pin on which it revolves; when going astern the strain is a compressive one on the links, and when folded the blades may be additionally secured by a cleat attached to the after-post.

The whole arrangement would be under the control of the engineer, without his having to leave the engine-room; he would be able to expand or contract the blades in a few minutes after the order was given, without stopping the progress of the vessel, or calling in the assistance of the crew.

The enormous price of coal renders necessary the economy of consumption of fuel, and although the route from Great Britain to parts within a certain radius, *via* Suez Canal, will necessarily continue to be performed by steam vessels independent of sails, there are distant parts where it would be impossible to make them pay. There is consequently, a large field open for a more economical class of vessels that would possess an advantage over an ordinary sailing vessel, and could be maintained with very little additional expense, and, in some instances, with equal dispatch as a full-power steam vessel.

A vessel for a long voyage would be of the following dimensions:—Length, 300 ft.; breadth, 40 ft.; depth of hold, 24 ft.; with accommodations for passengers, officers, and crew on deck, and a pair of direct acting engines placed at the after-part of the vessel, below the main deck, on the compound principle, capable of working to about 150 horse-power (indicated), with boilers to maintain a steam pressure of 60 lbs. per square inch. The consumption of coal would be about 72 cwt. per twenty-four hours, and the speed when under

*Paper read before Institution of Naval Architects by Henry Claughton, Esq.

steam would be about six knots in a calm, and as the steam power need only be used in emergency, such a vessel should perform a voyage to Australia, out and home, with 100 tons of coal.

It is not advisable to introduce steam power into sailing vessels of the present proportions and form, and the adaptation may only be advisable in such vessels as are well suited for the combination of sailing and steam. In a sailing vessel built from my design, the best day's work was from 330 to 360 miles, for nine days. It appears to be a great pity to dispense with sails when such results can be obtained, and if a small auxiliary power were introduced as above described, into a proper proportioned and well-formed vessel, it would be the most economical and effectual carrier for ocean navigation.

Messrs. R. Napier and Sons, Glasgow, have arranged to bring the propeller into use, but have had no opportunity of trying it as yet.

THE STRENGTH OF BUILDING MATERIALS.

From "The Builder."

Some very useful information on the strength of materials employed in general building is given, *inter alia*, in Mr. Stoney's valuable book on the Strains in Girders.* The nature of the strains produced in all horizontal beams— as bressummers, girders, joists, lintels, etc.—is alike in all. It is compounded of compressive strains in the side immediately loaded and of tensile strains in the opposite side; while the strains produced in pillars, columns, and struts are wholly compressive, and in tie-rods and tie-beams wholly tensile, except that in some forms of structure and mode of loading, struts and ties occasionally act in both ways, and in these cases require exceptional consideration.

Having ascertained by experiment the breaking weight of specimens of materials of known dimensions, the general custom is to take some sub-multiple of that weight as the safe load; as, for instance, where a bar of iron 1 in. square is found to break with a weight of 20 tons, it would be loaded with not more than, say, 5 tons, or one-fourth, as the working load.

The crushing strength of timber varies with its condition of dryness, being not nearly so strong when wet as when dry. The crushing strength in pounds per sq. in., when in its ordinary state, and when dry, is as follows, respectively:—Red deal, 5,748 and 6,586; white deal, 6,781 and 7,293; spruce fir, 6,499 and 6,819; mahogany, 8,198 and 8,198; Quebec oak, 4,231 and 5,982; English oak, 6,484 and 10,058; pitch pine, 6,790 and 6,790; yellow pine, 5,375 and 5,445; red pine, 5,395 and 7,518; willow, 2,898 and 6,128. These experiments, having been made with selected specimens of small size, show results in general much greater than can be reckoned upon in practice with large scantlings, subject to the defects of knots, etc., and probably about half these weights per sq. in. would represent the real ultimate strength of the respective kinds of timber. The working load should be only a fraction of this strength. At the Landore Viaduct, constructed by the late Mr. Brunel, of creosoted American pine, the timber was generally calculated to bear 373 lbs. per sq. in. in compression, though in some parts of the structure the strain was allowed to reach 560 lbs. At the Innoshannon lattice timber bridge, erected by Mr. Nixon, on the Cork and Bandon Railway, the ordinary working strain was 484 lbs. in compression. In America, General Haupt has not considered it safe to assign more than 800 lbs. per sq. in. as a permanent load; and in a paper read by Mr. Mosse, at the Institution of Civil Engineers, in 1863, it is stated that about 900 lbs. per sq. in. are usually considered by American engineers to be the limit of safe compression for timber framing (pine is the timber here meant). "Navier and Morin, distinguished French authorities, recommend that the working strain of timber should not exceed one-tenth of the breaking strain, and, owing to its liability to decay, this rule seems safe practice for structures which are exposed to the weather; but when timber is under cover, one-eighth of the breaking strain is a safe working load. For merely temporary purposes,

* The Theory of Strains in Girders and Similar Structures. By Bindon B. Stoney, M. A., M. Inst. C. E. New edition. D. Van Nostrand, New York, 1873.

a strain of one-fourth of the breaking weight is probably safe, provided there are no shocks." The experiments, the results of which are given above, were made with short pieces, not more in height than twice the diameter. With long pillars, however, the case is different, owing to the liability to bend under loads approaching the safe compressive strain of the wood itself. The square is the strongest form of rectangular timber pillar. It appears from Hodgkinson's experiments, that the strength of long, round, or square timber pillars is nearly as the fourth power of the diameter or side divided by the square of the length. The late Professor Hodgkinson gave the following rules for the strength of timber pillars with both ends flat and well bedded, and whose lengths exceed 30 times the diameter:—

Let W = the breaking weight in tons.
l = the length of the pillar in feet.
d = the breadth in inches.

For long square pillars of dry Dantzic oak,

$$W = 10.95 \frac{d^4}{l^2}.$$

For long square pillars of red deal (dry),

$$W = 7.8 \frac{d^4}{l^2}$$

For long square pillars of French oak (dry),

$$W = 6.9 \frac{d^4}{l^2}.$$

When timber pillars are less than 30 diameters long, they come under the class of medium pillars, for which Mr. Hodgkinson devised the following formula:—

$$W^1 = \frac{W c}{W + \frac{3}{4} c}.$$

where W = the breaking weight in tons derived from the formula for long pillars, on the hypothesis that the pillar yields by flexure alone; c=the crushing weight of a short length of the pillar, *i. e.*, its sectional area multiplied into the crushing unit strain of the material, in tons; and W^1 = the real breaking weight of the medium pillar, in tons, from the combined effects of flexure and crushing.

Pillars with flat ends, well bedded, are much stronger than pillars with round ends or those imperfectly bedded. "In all long pillars of the same dimensions the resistance to fracture by flexure is about three times greater when the ends of the pillars are flat and firmly bedded, than when they are rounded and capable of turning." The strength of pillars with one end flat and the other rounded, is a mean between that of a pillar with both ends round and one with both ends flat.

The crushing strength of granite of various kinds has been found to be as follows: Aberdeen (blue), 10,914 lbs. per sq. in.; Peterhead, 8,263; Cornish, 6,356; Killiney, 10,780; Kingstown, 10,115; Blessington, 3,630; Ballyknockan, 3,173; Newry, 13,440; Mount Sorrel, 12,861.

The strength of Arbroath paving stone (sandstone) is 7,884 lbs. per sq. in.; Caithness, 6,493 lbs.; Dundee sandstone, 6,630; Craigleith white freestone, 5,487; Bramley Fall, near Leeds, 6,059; Derby grit, 3,142 and 4,345; Yorkshire paving, 5,714. Compact limestone, 7,713 lbs. per sq. in.; black compact Limerick limestone, 8,355; Anglesea limestone, 7,579; Valencia slate 10,943; Killaloe, on bed of strata, 26,495; the same on edge of strata, 15,225; Glanmore on bed of strata, 21,315; on edge, 12,740.

The ultimate strength of bricks to resist compression is set down as follows: Pale red, 562 lbs. per sq. in.; red brick, 808 lbs.; yellow-face baked Hammersmith paviors, 1,002 lbs.; yellow-face burnt Hammersmith paviors, 1,441 lbs.; Stourbridge fire-brick, 1,717 lbs.; Buckley mountain brick, North Wales, 2,130 lbs.; brickwork set in cement (the bricks not of a hard description), 521 lbs. per sq. in. For the purpose of comparing the strength of Portland cement bricks with that of common bricks, Mr. Grant made some experiments, which were as follows ("Minutes of Proceedings, Inst. C. E.," vol. xxxii.): Gault clay brick, $8\frac{3}{4} \times 4\frac{1}{8} \times 2\frac{3}{4}$ bore a weight of 40.04 tons before crushing; a wire-cut brick of the same clay, $\frac{1}{4}$ in. longer than the last named, 32.70 tons; a perforated gault clay brick, 9 in. long, $4\frac{3}{8}$ in. wide, $2\frac{5}{8}$ in. thick, 46.40 tons; Suffolk brimstones $9 \times 4\frac{1}{2} \times 2\frac{5}{8}$, 34.94 tons; Stock brick, $9 \times 4\frac{1}{8} \times 2\frac{5}{8}$, 38.74 tons; Fareham red brick, $8\frac{3}{4} \times 4\frac{1}{8} \times 2\frac{5}{8}$, 90.40 tons; Staffordshire blue brick, pressed with frog, $8\frac{3}{4} \times 4\frac{1}{8} \times 2\frac{3}{4}$, 111.04 tons; the same kind of brick without the frog, 117.92 tons.

The late Professor Rankine considered the crushing strength of good coursed rubble masonry to be about four-tenths of that

of the stone of which it is built. The resistance of common rubble to crushing is not much greater than that of the mortar which it contains. The following is the crushing strength of lime mortar, according to Rondelet, in pounds per sq. in.: Lime and river sand, 436 lbs.; the same beaten, 596 lbs.; lime and pit sand, 578 lbs.; the same beaten, 800 lbs.; cement and pounded tiles, 677 lbs.; the same beaten, 929 lbs.; these mortars were eighteen months old. Fifteen years later the experiments were repeated, when mortars of lime and sand were found to have increased in strength about one-eighth, and mortars of cement about one-fourth.

Some examples of the actual pressure sustained by stone and brick of various kinds are given, the greatest of which appears to be in the pillars of the church of All Saints at Angers, of Fourneaux stone, viz., 38.4 tons per sq. ft. The pillars of the dome of St. Peter's, at Rome, carry a weight equal to 14.9 tons per sq. ft., and are of calcareous tufa, called Travertin. The pillars of the dome of St. Paul's, London, of the oolitic limestone of Portland, carry 17.6 tons per sq. ft. A pillar in the Chapter-house of Elgin, of red sandstone, carries 17.9 tons per sq. ft. Red Birmingham bricks in a viaduct in that town, set in lias-lime mortar, carry 7 tons per sq. ft. London paviors, set in mortar of 1 of cement to 2½ of sand, in the Charing Cross railway bridge, carry 12 tons per sq. ft. Staffordshire blue bricks, set in Portland cement, in Clifton Suspension Bridge, 10 tons per sq. ft. Concrete, made of 1 of Portland cement to 7 of Thames gravel, carries 8 tons per sq. ft. in Charing Cross bridge.

Experiments on the crushing weight of cast-iron from sixteen localities, showed a mean of 38.519 tons per sq. in., the specimens experimented on being one diameter and two diameters high, an equal number of each. The weakest of these was 27 004 tons, and the strongest 49.109 tons. Another set of experiments on twenty-two different sorts of cast-iron, showed a mean crushing weight of 37.6 tons per sq. in.; the weakest being 24.45 tons, and the strongest 51.78 tons. The strongest specimens were mixtures of different sorts of iron.

Repeated meltings seem to have the effect of increasing the crushing strength, which may be said to be in general about 42 tons per sq. in. for mixtures, but for simple cast iron to be somewhat less than 38 tons. In practice, however, these pressures seem never to be nearly approached. For instance, in the Severn Valley railway bridge, carrying the Coalbrook-dale railway, 200 ft. span, and 20 ft. rise, the calculated working strain is between 2½ and 3 tons per sq. in. In the centre arch of Southwark Bridge, 240 ft. span, it is 2 tons per sq. in. In subjecting wrought iron to a compressive strain, its greater elasticity must be taken into account. Ordinary wrought iron is completely crushed, *i. e.*, bulged, with a pressure of from 16 to 20 tons per sq. in., and the point at which compressive set sensibly commences, *i. e.* the limit of compressive elasticity, is about 12 tons per sq. in.

The tensile strength, on the other hand, is greater in wrought than in cast iron. The mean tensile strength of 27 sorts of cast iron was 7 tons, the weakest being 5.667 tons, aad the strongest 10.477; whereas Mr. Kirkaldy found the mean tensile strength of 188 rolled bars to be 25¾ tons per sq. in.; of 72 angle irons and straps, 24½; of 167 plates lengthwise, 22.65 tons, and of 160 plates crosswise 20.6 tons. Timber is put to better use when so placed as to receive a compressive strain in the direction of its fibre than when employed as a tie; nevertheless, as it is sometimes used for this purpose, a few examples of its tenacity may be quoted. Christiana deal is set down as having a tensile strength of 12,900 lbs. per sq. in.; elm, 14,400 lbs.; fir, 12,000 lbs.; mahogany, 8,000 lbs., according to Barlow, but according to Bevan, much more; English oak, 10,000 lbs.; pitch pine, 7,650 lbs.; Norway pine, 7,287 to 14,300 lbs.; Petersburg pine, 13,300 lbs.; teak, 15,000 lbs. These are lengthwise of the grain, but in tearing the fibres asunder crosswise, the following numbers are given in pounds per sq. in.: Memel fir, from 540 lbs. to 840 lbs.; Scotch fir, 562 lbs.; larch, 570 lbs. to 1,700 lbs.; oak, 2,316 lbs.

As stone is rarely employed in direct tension there are but few experiments on its tensile strength, but the following are given of some Scotch stones, viz.: Arbroath paving, 1,261 lbs. per sq. in.; Caithness, 1,054 lbs.; Craigleith, 453 lbs.; Hailes, 336 lbs.; Humbie, 283 lbs.; Binnie, 279 lbs.; Redhall, 326 lbs., Whinstone, 1,469 lbs. The tensile strength of mortar is more often use-

ful, and is as follows, according to M. Vicat: Mortar of quartzose sand, and eminently hydraulic lime, well made, 136 lbs. per sq. in.; of quartzose sand and ordinary hydraulic lime, well made, 85 lbs; of quartzose sand and ordinary lime well made, 51 lbs.; mortar, badly made, 21 lbs.

When a beam projects from a wall, and is loaded, either at the extremity or uniformly over its length, the upper edge is extended and the lower edge compressed. This projecting beam may be called a semi-girder. The relative strength of beams or girders is proportional to the breadth, to the square of the depth, and inversely proportional to the length; or in other words, it is proportional to the cross-sectional area multiplied into the depth, and divided by the length. The absolute strength varies with the material, and is determined for each kind of material by experiments, from which are deduced from each the co-efficient of rupture, S.

When a semi-girder is loaded at the extremity $W = \frac{a\,d\,S}{l}$, and $S = \frac{l\,W}{a\,d}$, in which W = the breaking weight, a the sectional area, d the depth, and l the length, S being the constant determined for each material, by finding experimentally the breaking weight of a girder of known dimensions, and similar in section to that of which the strength is required. For small rectangular cast-iron bars, not exceeding 1 in. in width, S=3.40 tons. For large rectangular cast-iron bars, say 3 in. wide, S = 2.25 tons.

For Christiana deal S=1,562 lbs.; English elm, 782 lbs.; Canada rock elm, 1,970 lbs.; Mar Forest fir, 1,232 lbs.; spruce fir, 1,346 lbs.; American hickory, 2,129 lbs.; Australian iron bark, 2,288 lbs.; Norway spar, 1,474 lbs.; African oak, 2,523 lbs.; Dantzic oak, 1,518 lbs.; English oak, 1,694 lbs.; American red pine, 1,527 lbs.; pitch pine, 1,727 lbs.; American white pine, 1,229 lbs.; American yellow pine, 1,185 lbs.; Dantzic pine, 1,426 lbs.; Memel pine, 1,348 lbs.; Riga pine, 1,383 lbs.; teak, 2,108 lbs.; South African sneezewood, 3,305 lbs.

The foregoing values of S for timber are derived from selected samples of small scantling, perfectly free from knots and other imperfections that cannot be avoided in large timber, and the few experiments recorded on balks of large size indicate that the values of S must be reduced to nearly half (.54 times) those given above.

By mechanical reasoning, as well as by experiment, it is found that beams will carry various weights, the dimensions being the same, according to the manner in which they are loaded, *e. g.*, for a semi-girder, loaded uniformly, $W = \frac{2\,a\,d\,S}{l}$.

For a girder supported at both ends, and loaded at the centre, $W = \frac{4\,a\,d\,S}{l}$.

For a girder supported at both ends, and loaded uniformly, $W = \frac{8\,a\,d\,S}{l}$.

For a girder supported at both ends, and loaded at an intermediate point, the segments of the length being called m and n respectively, and $m + n$ being equal to l, $W = \frac{a\,d\,l\,S}{m\,n}$.

It is often very useful to know the transverse strength of stone. The author gives the following values of S for several kinds. Of granite, the following: Ballyknocken, co. Wicklow, 109 lbs.; Golden Hill, Blessington, 76 lbs.; Killiney, co. Dublin, 270 lbs.; Kingstown, co. Dublin, 346 lbs.; Newry, co. Down, 340 lbs.; Taylor's Hill, Galway, 407 lbs.

Of sandstones and grits: Green-moor, Yorkshire, blue stone, 335 lbs.; white stone of the same locality, 359 lbs.; Caithness stone, 857 lbs. Of limestone from Listowel quarry, co. Kerry, 414 lbs.; Ballyduff, King's county, 351 lbs.; Woodbine quarry, co. Kildare, 283 lbs.; Finglass quarry, co. Dublin, 291 lbs.

Valencia slate, on edge of strata, 1,091 lbs.; the same on bed of strata, 951 lbs.; Glanmore, co. Wicklow, on bed of strata, 1,097 lbs.; Killaloe, Tipperary, on bed of strata, 1,233 lbs.; Welsh slate, 1,961 lbs.

The strengths of the Irish stones are taken chiefly from Mr. Wilkinson's experiments, which were made on stones, 3 in. square and 12 in. clear length, of bearing, the pressure being applied on the middle of the length.

The working strain put upon any material compared with its ultimate strength, must be regarded in connection with the nature of the material; the more fibrous the material, the nearer may the working load approach the ultimate strength, within the limits of convenience in respect of bending.

GEODETIC OPERATIONS IN ALGERIA.

From "Nature."

The idea of prolonging the French arc of meridian to Sahara by the direct trigonometrical junction of Spain and Algeria, an idea of undoubted scientific value, presented itself to the mind of Captain Perrier when he was collecting the preliminary materials for the survery of Algeria. That survey was begun at the same time as the conquest, in the middle of military operations.

The design was to calculate two great lines conforming to parallels, and transversely cut by three meridians; quadrilaterals would be thus formed, completed by triangles of the first order. Only a linear chain was, however, drawn, except in the mountainous regions, where the operations would have been attended with too many difficulties. This chain connected with the sea by three excellent bases, would serve the purpose of adjusting and arranging the detailed operations. French geodesy thus measured an arc of latitude cutting the Paris meridian and extending from Morocco to Tunis, with a length of 990 kilometres.

The chain of first-order triangles may be divided into two parts, the first from Blidah to Tunis, measured by Captain Versigny; the other, more recent, measured by Captain Perrier.

The admirable choice of triangles, stations, and signals, is noteworthy. Those signals have been built by the observers themselves, as there were no steeples. The precision obtained is remarkable. In the sum of the three angles of any triangle, the error is about 3.12 sec. (centesimal seconds)* in M. Versigny's operations (who made use of Gambey's repeating circles); the error is about 3.07 sec. in M. Perrier's operations, who made use of Brunner's excellent azimuthal circles. In order to measure the bases, the system of M. Porro, an Italian engineer, has been employed, in preference to the old method of Borda, and it has been followed by the best results.

Colonel Levret proved (in 1869), by very exact calculations, that the passage by Gibraltar could be dispensed with, and that it would be possible to communicate between Spain and Algeria, in spite of the immense distance between the two continents. The entire certainty of that posibility has been proved by Captain Perrier, who has pointed out in a precise manner the names and positions of the visible summits and the length of the sides of the new chain.

It was only on October 18, 1868, that he managed to perceive the Spanish shore; he saw it from Seba Chioukh, near the mouth of the Tafna, very distinctly and without the glass. A serrated ridge was to be seen in the distance, toward the north-west, with five prominent summits. The distinctness was so perfect, that he could discern with his naked eyes the different parts of those mountains, those which were in the shade and those illuminated by the sun. He thus measured azimuths with the summit of the Tessala, the zenithal distances of the two highest points of the ridge, and the zenithal distance of the horizon of the sea.

After his return to France, he compared his measurements with the survey of Spain, made by Colonel Cuello, and concluded that he had observed the Mulahacen of the Sierra Nevada, and the peak of Sagra of the Sierra Sagra, the highest points of the Sierras of the Province of Granada.

In Spain the peaks of Sagra can be seen from Mulahacen; those mountains belong to the primordial geodetic chains of the Iberic peninsula. In Africa the points of the quadrilateral (Bem Saabia, Tessala, Filhaoussen, and Nador) are reciprocally visible, and the three last are situated in the primordial chain of Algeria.

With these points, Captain Perrier was enabled to form a chain common to Europe and Africa. Leaving the station of Seba Chioukh as superfluous, as well as the direction of Nador Sagra as being too close to the horizon of the sea, he delineated that immense pentagon formed by the five summits of Mulahacen, Sagra, Bem Saabia, Filhaoussen, and Nador, every side and diagonal of which except one, are the directions that are to be observed. He has even calculated and valued in round numbers the length of the sides of this geodetic chain. He has found—

	Metres.
Mulahacen-Filhaoussen	273,400
" Nador	314,500
" Bem Saabia	272,200
Sagra-Filhaoussen	313,300
" Bem Saabia	271,000

* One centesimal second = 0.33 min. ordinary second.

The length of the terrestrial sides are—

	Metres.
Bem Saabia-Filhaoussen	109,800
" Nador	104,800
Mulahacen-Sagra	113,900

With those approximate numbers (and valuing at 0.08 the coefficient of refraction) he has calculated the altitudes of the two Spanish mountains. The measures thus obtained differ little from the real numbers—

	Metres.
Mulahacen	3,994
Sagra	2,398

given by Colonel Cuello, and thus furnish a new verification.

As the geodetic operations are being continued with great actively in Spain and in Algeria, we may hope that in a few years the geodetic bases of Great Britain, of France, Spain, and Algeria, reduced to the same unit of measure, can be connected by continual chains of triangles; and the meridian line of France already prolonged northward to the Shetland Islands, carried out in Spain by the officers of that country, will reach the African Continent and extend to the Sahara with a length of 30 deg.

France will then be able to oppose to the Russian arc and to the one measured in Central Europe the French arc, which, passing over plains and very high mountains, will cross the North Sea and the Mediterranean.

There is thus considerable truth in the words of M. Faye: "Let us not forget that the French, who are at the present time so often reproached with their geographical ignorance, are the real creators of continental or maritime geodesy, and that they have continually, since Cassini to our days, published admirable geodetic papers, which have served as models to our rivals; the truly learned men abroad have always acknowledged their value."

The map of Algeria will be constructed on the same plan as the map of France, to the scale of $\frac{1}{80000}$, but as it will be colored, and as level curves will be substituted for hatchings, it will have considerable advantages over the latter.

USE OF THE PLUMMET LAMP IN UNDERGROUND SURVEYING.*

By ECKLEY B. COXE.

From the "Engineering and Mining Journal."

In the anthracite coal regions of Pennsylvania the custom has been to sight either at an open light (generally a mine lamp), or at the string of a plumb-bob. If the station was intended to be a permanent one, a spud, as it is called, that is, a nail resembling a horse shoe nail with a hole in the head, is driven into the timbers over the station, or, if there be no timber, a hole is drilled in the coal or rock roof, into which a wooden plug is driven, which serves to hold the spud.

The first operation in making a survey, is to lay out the stations, that is, to mark the place where the holes are to be drilled for the plugs or the points on the timbers where the spuds are to be driven in. This should be done before any instrumental work is begun, as much labor can generally be spared, and the use of very short sights can often be avoided, by carefully laying out the stations before hand. When the stations were laid out, a plumb-bob was hung from the innermost spud, which I will call No. 1; the instrument was put in position at No. 2, by plumbing down and putting a centre pin under the spud, and then setting up over the centre pin, and another plumb-bob was suspended from No. 3. If great accuracy was not required, a mine lamp was set up under the plumb-bobs at No. 1 and No. 3, and the engineer sighted at them. If great accuracy was required, a lamp or some white surface was held by an assistant behind the strings of the plumb-bobs. To work with any speed by the latter method (*i. e.*, the accurate one), it was necessary for the engineer to have three assistants on whom he could rely even when the chaining was done afterwards; viz.: one to hold the light behind the string at No. 1, one at No. 3, and an assistant at the instrument to hold the light while levelling, reading the instrument, etc. When using lamps on the ground, it is necessary to examine them from time to time to see that they have not sunk in the mud or turned on one side, etc. Besides, the flame of a mine lamp is a very large object to sight at, and sometimes it is impossible to

*A Paper read before Am. Institute of Mining Engineers.

see it on the ground (when it can be well seen 2 or 3 ft. above it), in consequence of some intervening obstacles. Being so situated that it was necessary for me to do a certain amount of accurate work, where I could not rely upon having more than one competent assistant, I had the plumb-bob lamps constructed, and I work with them with a single assistant in the following manner:

When the stations have been laid out, I go to station No. 2 with the transit, and by means of the plumb-bob belonging to the instrument, I place the centre pin (a small block of lead with a steel pin in it) precisely under the spud No. 2; I then remove the plumb-bob and set up my instrument. While I am doing this, my assistant takes the two lamps, suspends one from spud No. 1, and the other from spud No. 3, and then comes back to hold the light for me while I make the final adjustments and take the readings. My instrument is graduated to 360 deg., and has two verniers 180 deg. apart. I set the vernier at zero, and sight backwards to lamp No. 1. The flame is very small and has a blue central cone, which I bisect. I then read the compass needle, invert the telescope, deflect and sight at No. 3, and read both verniers and the needle. I then turn the telescope back, sight upon No. 1, and turn the vernier plate round nearly 180 deg., until I sight No. 3, and again read both verniers. I obtain thus four readings of the deflection from the vernier, and a compass reading as a check, and as the lights are steady and small, the readings can be made very accurately and quickly. If the four readings agree (with their difference of 180 deg.) I am sure there is no mistake and go on. I then take up my transit, go to No. 3, run down the lamp to near the ground, put my centre pin under it, remove the lamp and begin to set up.

In the meantime, the assistant brings the lamp from No. 1 to No. 2, and then takes the lamp from No. 3 to No. 4, and comes back to No. 3 to assist me at the reading of the instrument. The work goes on in this way until all the angles are measured. I then go back and chain the distance from one station to another, and take notes of the workings, etc. In this way, two persons can make a very accurate survey as quickly as three can by the old method. Of course if one has assistants enough the chaining can go on with the instrumental work.

DR. WEDDING ON THE WORKING OF BLAST FURNACES WITH RAW COAL AT GLEIWITZ IN UPPER SILESIA.*

From "Journal of Iron and Steel Institute."

Coal was used in the blast furnace before coke came into use. In England, the earliest experiments, mostly unsuccessful however, to substitute mineral fuel for charcoal, were made by Dud Dudley in 1620, and after many years, when the results of the former experiments were almost forgotten, by Abraham Darby, in 1730. Coal, in some cases alone, in others mixed with coke, was not employed with promising results in the blast furnace till after the introduction of the hot blast; first in Scotland in 1830, then in South Wales and South Staffordshire, and in 1840 in North America. About this time, a few unconnected experiments with the same object in view were made on the Continent, in France at Decazeville, in Upper Silesia at Konigshutte, between the years 1835 and 1837. On the blowing in of the "Wedding" furnace at the latter works in 1835, after good results had been obtained from using raw coal, endeavors were made to increase the profits by using this fuel, resulting, however, in the discovery that the temperature in the furnace decreased, instead of increased, as was expected. In the year 1835, with a mixture by volume of $\frac{1}{3}$ coal and $\frac{2}{3}$ coke, better results were obtained; but nevertheless, so many difficulties, such as the irregular descent of the furnace charges, had to be encountered, that after a final endeavor in 1837, the attempts to use coal were again abandoned. The next experiments on a large scale passing over the failures at Friedrichshutte in 1857 and 1858, took place in 1852 in Königshütte. These, conducted by Herr Erbreich, and described at length by him in XI. Vol. of these Transactions, showed however, in spite of the great care and forethought with which they were conducted, at the stage when they were sus-

*Translated from the German, by Mr. Ernest Bell.

pended, no particularly promising results. The number of charges per day when working with coal alone decreased about 20 to 25 per cent., and, indeed, after three or four weeks, 50 per cent. In the well of the furnace the metal and slag were at a remarkably low temperature. The metal was solid in fracture, mottled, and at the edge white, showed little strength, was with difficulty melted in the puddling furnace, but soon balled, and yielded undurable short-fibred malleable iron, containing little carbon, with a very high percentage of silica. After working four weeks, it became necessary again to use coke, owing to the hearth growing up and the furnace scaffolding. Even an increase in the temperature of the blast (from 250 to 330 deg. C) did not improve the working of the furnace. The burden in the blast furnace consisted of calcined clay-ironstone, mill cinder, and limestone. The furnace was of the following dimensions:—Height, 15.22 metres; width at throat, 2.59 metres; bosh, 4.65 metres; and at the level of the tuyeres, 6 in number, 1.26 metres. In a second series of experiments, the fuel consisted of, by volume, one-half of coal. At first, the burden was calcined brown hematite with raw limestone, and afterwards raw hematite with burned limestone. With this burden, although the working condition of the furnace was good, the production decreased, the quantity of fuel consumed was greater and consequently the cost price of the metal, which had deteriorated in quality, was higher.

According to these results, it was inferred: That the brown hematite of Upper Silesia could not be smelted either with raw coal alone or with a mixture of coal and coke in equal proportions: That even a much less proportion of coal than one-half would, in all probability, be inadmissible: That the cause of failure was possibly due to the poverty and decomposed state of the ore, which differs from that of England, where raw coal is successfully used: That the use of raw coal, instead of coke obtained from the same coal, changed the condition of the furnace by virtue of the cooling effect of the operation of coking, which, when the fuel is used raw, goes on in the furnace itself.

The conclusions were evidently too sweeping, although the explanation of the failure of the experiments must be regarded as correct. This erroneous conclusion finds an explanation in the untenableness of the theory by which it was sought to connect the cause and effect. It was assumed that in every blast furnace there existed two distinct zones, being characterized by prevalence, in the upper one of carbonic oxide, in the lower of carbonic acid, and that the working of the furnace depended principally on the relative space occupied by these two zones. Since that time, however, it has been satisfactorily proved that the quantity of carbonic acid gas in the blast furnace gases at the tuyeres is, under all circumstances, very small, therefore the question of a great height of zone of carbonic acid gas cannot exist; that the quantity of carbonic acid gas near the tuyeres is dependent on conditions (temperature of blast, strength of blast, etc., etc.) existing outside the furnace. If we substitute, therefore, "reducing" and "melting" for "carbonic oxide" zones, and look for their difference in the difference of the temperatures of their respective gases, the foregoing may be regarded as correct.

The difference which is apparent in working a blast furnace with coal, and the same furnace with coke manufactured from precisely similar coal, the rest of the burden in both cases being the same, is easy of explanation. In the first case, the volatile substances are driven out of the coal in the furnace; while in the latter case, it is done in the process of coking outside the furnace.

The combustible part of the fuel, by the time it comes opposite the tuyeres, differs in either case but slightly. Small differences may exist in the possibility of diminishing the quantity of sulphur (in coke already diminished about one-half by its being cooled with water) by evaporation in the reducing atmosphere of the furnace; also, in the greater density of coke made under pressure in the furnace. The escaping gases are not different when using coal. The causes of the difference in the results obtained when working with raw coal are —Firstly, that heat is consumed in the process of coking, and, therefore, lost to the zone in which the process takes place, which is not the case when using coke; secondly, that the coal, and also the gases generated during the process of coking, occupy a greater space. These two causes tend to diminish the temperature in that part of the furnace where the coking takes place, and indirectly, therefore, reduce the temperature of the whole. The heat which

is lost in these ways can be tolerably accurately determined by comparing the quantity of escaping gases when using coal, with the quantity when using a corresponding quantity of coke. In other words, we regain the heat lost when using coal by utilizing the escaping gases. This loss of heat in the furnace explains the phenomena and results of the experiments carried out at Konigshutte and elsewhere. As regards the quantity of fuel, a complete saving when using raw coal can only be effected by preventing the loss of carbon arising from an imperfect method of coking (such as, for example, open clamps, heaps, etc., etc.), and the loss arising from drawing and transporting the coke. As regards other circumstances which tend to reduce the temperature, first, that coal will have the least cooling effect which absorbs least heat before it arrives at the burning point, therefore, the least gaseous; and, secondly, the cooling effect will be more apparent the greater the proportion of the ores and flux to the coal. The poorer the ores the more flux they require.

This loss of heat will be apparent by the delay in the reduction, and if not remedied, by the imperfect reduction of the ores in the higher part of the furnace, by the presence of unreduced ore in the melting zone, by the consumption of carbon for reduction in the melting zone, and, at the same time, by a greater and greater loss of heat, resulting in dull iron containing large quantities of silicates and carbon, and ending in the furnace being gobbed up and entirely losing heat.

It has not been said, however, that these difficulties cannot with proper arrangements be overcome, even in cases where many unfavorable circumstances are combined, where the coal is very gaseous and the ores poor, and require much flux. A remedy in such cases lies in the shape of the furnace. To this circumstance, which has already been impressed upon you by the author in 1861, enough attention is not always paid. That which was wanting in the old furnace has been carried out in the new construction. In the first place, a well of a greater diameter is necessary, in order that by increasing the number of tuyeres, a corresponding combustion of carbon in a unit of time may result, and in consequence of this a proportionate decrease of radiation and an increase of production, and a higher temperature. The temperature cannot be increased, as is the case when using coke, by the simple addition of more fuel in proportion to the quantity of ore, because the greater the charge of fuel the greater the loss of heat by coking. Hot blast is requisite, owing to the greater density of the coke produced. With these exceptions, no other arrangements are necessary, other than those required when working with coke. If we proceed without changing the diameter of the well and the pressure of the blast, and use instead of cold, hot blast, we not only do not gain, but lose, because the volume of oxygen per unit of time going into the furnace is reduced. Further, wide throats are necessary in furnaces using coal, in order to lessen the velocity of the falling material, and of the escaping gases in the upper and middle parts of the furnace. Calcining the limestone and in particular instances the ores, will materially prevent loss of heat, because the heat consumed to effect this in the furnace will be more advantageously utilized. Hereafter, we may take for granted, that by a proper construction of furnace, coke may under all circumstances be superseded by coal; but whether this change is advantageous, and therefore economical, depends upon the circumstances of each individual case. Coking coal must, however, from the first be discarded. 1st. Owing to the trouble caused by large pieces of coke being formed in the furnace; and 2d, owing to the ease with which small coal, which is injurious when used in a raw state, can be coked. On the other hand, no bituminous coal, which as small coal is not advantageously converted into coke, is in its raw state, when found in the neighborhood, the proper material for working the furnaces.

It is, therefore, somewhat easy to foresee that in the course of time, in the blast furnace district of Upper Silesia for instance, where the main supply of fuel is non-bituminous, it must be consumed in a raw state in the blast furnaces, and if this should not altogether succeed, then from the small coal a suitable coke must be manufactured, which necessitates coke ovens constructed for the purpose. The failures of the experiments of Herr Erbreich must not daunt, but, on the other hand, give encouragement to make use of the knowledge already gained in carrying out now experiments on a more judicious plan. At works where the coke and coal have to be bought at a distance, and where a choice

has to be made between the two materials, and often between different qualities of them, the question what fuel is most economical is much more important; because it is materially influenced by many circumstances which would otherwise not be considered, for example, the cost of transport. The works at Gleiwitz find themselves placed in the latter predicament; there, as will be proved further on, the price of the various fuels, bituminous coal, non-bituminous coal, and the coke made from each, did not differ materially. Under these circumstances, therefore, the task of reducing the cost of metal by using raw coal was a difficult as well as a desirable one. It was intrusted to Herr Wiebmer, who is well known for his report of his visit to England, and his researches on the hot-blast.

Before the beginning of the experiments detailed in this paper, working with raw coal was already recommenced at Antonienhutte, in Upper Silesia; and with an addition of coke, good results were obtained. With acknowledged promptness, the managers of these works communicated the results of the experiments to Herr Wiebmer, and with their co-operation the results were obtained at Gleiwitz. The results at both places show that an addition of coal is advantageous.

In the year 1869, two furnaces, Nos. I. and IV., were worked at Antonienhutte, to determine the difference of management when working with coke and with coal. No. I. furnace was worked entirely with coke; in contrast, No. IV. was worked the greater part of the time with the highest, and what was then thought the most advantageous addition of coal, viz., two-thirds by volume, and for a short time partly with coke alone, same as No. I., and partly with coal alone.

The results obtained from using coke alone were, it is true, very good; but the economical aspect, as compared with the results when using an addition of raw coal, was not so favorable, the latter being much cheaper. On the other hand, the three weeks' trial with raw coal did not give satisfaction, although endeavors were made to maintain the temperature by using burned limestone. In spite of this, the furnace cooled so considerably that the daily charges decreased about 30 to 50 per cent., causing deposits on the sides and bottom of the well. The cost price of the metal was very high, and the quality inferior.

In order to prevent the furnace going out, and to raise it to a heat at which it would work, it was necessary to charge for some length of time with coke.

The results were similar if raw limestone was used when working with two-thirds by volume of coal.

From these results it was now seen that one of the operations necessary to make the experiments with raw coal at Antonienhutte successful, was burning the limestone before putting it into the furnace, although it increased the cost of the flux 4 lbs. per centner of metal. On the other hand, preparing and calcining the ores had to be abandoned, because the expense was so great as to preclude the possibility of an economical advantage.

It was ascertained at Antonienhutte, as at Konigshutte in 1862, that when working with raw coal, no higher pressure of blast is required than when working with coke made from that coal.

For some time it was the impression, that to consume coke made under a great pressure in the furnace, a higher pressure of blast was necessary; and therefore the pressure was raised to 4 lbs., but with unfavorable results, however. On reducing it to the usual pressure—viz., 3 lbs. per square inch—the furnace worked satisfactorily. During the time No. IV. was being worked with coal, the blast entered through eight tuyeres, each 3 in. diameter.

It is supposed that having numerous tuyeres, of small diameter compared to those used when working with coke, adds materially to the success of the experiments when using raw coal. Although it has always been affirmed that a high temperature of blast is necessary to work with raw coal, it was nevertheless found that from 240 deg. to 300 deg. (C) were sufficient, and this was mentioned because any increase was found to deteriorate the quality of the metal. It was ascertained that No. IV. furnace worked better with raw coal, owing to its increased width consequent on its age, while with No. I., which had a new and comparatively narrow well, the experiments were not so satisfactory. A very wide throat was not found to be absolutely necessary. No. IV. had a well of 7 ft. in diameter, and a throat 9 ft. No. II., which was blown in at Antonienhutte in 1870, is of the following dimensions:—Height, 13. 15 metres; width of throat, 4.71 metres; of bosh, 5.65 metres, and has 8 tuyeres in

the plane of the well, which is 2.35 metres in diameter. From this furnace, with a mixture of $\frac{3}{4}$ coal and $\frac{1}{4}$ coke with burned limestone, good results as regards fuel consumed were obtained. From this it would appear that a wide throat is advantageous when using coal. This furnace, however, has not worked successfully with raw coal alone. The addition of coal has not deteriorated the quality of the metal, a fact which has been proved by frequent chemical analyses.

This metal, when mixed with metal made with coke, works well in the puddling furnace, and on this account is in great demand.

No difficulty was experienced at Antonienhutte, with the above stated quantity of coal, in obtaining, when the furnaces were in good working order, different qualities of metal, such as No. I. foundry, and forge. Indeed, the furnace has been driven for a considerable time with the smallest possible quantity of fuel, and a white metal has been the result, which is used at many puddling works, in preference, because it soon balls.

It is of much greater importance, to Antonienhutte, that coal should be used in its raw state in the furnace, because their coal is so non-bituminous that only the large pieces can be used in coking; besides, the loss in coking is very great and the coke brittle, and soon falls into small pieces, and therefore will only bear a small weight in the furnace.

Although the quantity of fuel consumed, when working with a mixture of coal, is just as large as when working with coke alone, there is still a saving, in spite of the extra flux required, owing to the low price of coal compared to coke.

The similarity of the results at Antonienhutte and Gleiwitz cannot be doubted, more particularly because lately the coke at Antonienhutte was not made from non-bituminous coal, but from coking coal from the Konigin-Louise pit; besides, this coke is, notwithstanding the high dues, much cheaper and better than the coke used at Gleiwitz.

However, there is a very important difference between the use of coal at the two places, viz., the price of large coal at Gleiwitz is much higher than at Antonienhutte, and therefore an equal saving was not to be expected.

On the other hand, another circumstance had to be considered at Gleiwitz, which but for the fact that no direct economical advantage was expected, would by its importance have helped to rectify the protracted attempts in this direction. Lately, by using unclean water in the boilers, they became so encrusted that the furnace gases would no longer both raise steam and heat the blast. It was, therefore, not improbable that, by using even a small quantity of coal in the furnace, firing the boilers with small coal would be unnecessary, and thus a saving be effected.

The experiment was carried on in June, July, and August, 1870, at the Karsten furnace. The results are shown in the accompanying table.

In this experiment large coal from the Konig pit was used, because it was cheaper than coal from the Konigin-Louise pit which would not bear carriage better than coke. Also, the coke made from it will carry a much greater burden than coke made from the Zabrzer coal.

The ore used throughout was brown hematite from the Perschtry mine at Tarnowitz. The use of clay ironstone was, owing to its high price at Gleiwitz, out of the question. Neither were the ores calcined, because the large outlay necessary for the plant, it was feared, would materially diminish the profits. On the other hand, for several rounds burned limestone was used. The existing kilns were not sufficient; it was therefore necessary to burn the limestone in clamps. This mode is not to be recommended unless fuel is very cheap, and not even then, because in wet weather, which was the case at Gleiwitz, the burned limestone is reduced to a powdered hydrate by the action of the rain, and thus rendered useless for the blast furnace.

I may here remark that two furnaces such as those at Gleiwitz require four lime-kilns, which would cost 8,000 thlr. to erect.

From the accompanying table it will be seen that one ctr. burned limestone costs 4 sgr. 7 pf.; therefore, by using it, the cost price of metal was increased 1 sgr. per ctr.; while at Antonienhutte, where fuel is cheaper, and where less loss occurred, the cost of production was only increased 4 pf. per ctr.

The following are the dimensions of the Karsten furnace, in which the experiments were made, it being considered the best

adapted:—Height, 15.06 metres; width of throat, 2.35 metres; of bosh, 4.39 metres; and with eight tuyeres in the tuyere plane, which was 2.20 metres in diameter. These dimensions are very much the same as those of No. IV. furnace at Antonienhutte, which has, however, a somewhat wider throat.

In conclusion, I may remark as follows on the experiment stated in the accompanying table.

For the sake of comparison, I have placed those experiments first in which most charges were consumed. The metal made was m stly a large crystalled foundry, well adapted for such ordinary castings as do not require to be worked up, because, after being melted in the cupola furnace, it becomes too dense in the skin.

1st Exp. Fuel consisted of $\frac{1}{2}$ coke and $\frac{1}{2}$ raw coal; flux raw limestone. After a few rounds, an unusual stream of gas was noticed in the boiler flues. By the time the rounds descended to the well, the furnace was doing such good work that the amount of ore was increased 15 lbs. per round, without lessening the work of the furnace. The metal made was large crystalled, and flowed somewhat faster than that made with coke; otherwise it was very similar.

2d Exp. Fuel consisted of $\frac{5}{6}$ coke and $\frac{1}{6}$ raw coal; flux of raw limestone. The larger addition of raw coal was beneficial. The heat increased in the well, the rounds were more frequent, and the slag very hot. Without increasing the temperature of blast, the quantity of ore was increased 25 lbs. per round. At the same time, the quantity of flux was diminished. These improvements were attributed to the greater purity of the coal from the Konig pit, compared to the Zabrzer coke. The quantity of gas given off was so great that firing the boilers and heating stoves was no longer necessary, and a saving of 12 tons per day of small coal was effected. The metal was large-grained, and better than that with coke, because it was more fluid; and after being melted in the cupola furnace, was soft and capable of being worked up.

3d Exp. Fuel again $\frac{5}{6}$ coke and $\frac{1}{6}$ coal; flux, burned limestone. No effect was produced by using burned limestone during three days' trial. The results were very similar to those of the 2d experiment.

4th Exp. Fuel, $\frac{2}{3}$ coke and $\frac{1}{3}$ raw coal; flux, raw limestone. The furnace had to be charged slower, and the quantity of ore per round in Nos. 2 and 3 experiments had to be reduced, in order to drive the furnace regularly. The quantity of gas given off increased. This, however, was no gain, because the gases given off in the former experiments, when only a small addition of coal was being made, more than sufficed to raise steam and heat the blast. The tension of the gases at the throat of the furnace became so great that the safety chimney had to be opened.

5th Exp. Fuel, $\frac{3}{4}$ coke and $\frac{1}{4}$ coal; flux, burned limestone. Burned limestone lessened the temperature in the well, and slightly reduced the number of rounds and the yield.

The metal was large crystalled, and resembled coke-made metal; it was, however, still adapted to foundry purposes.

6th Exp. Fuel, $\frac{7}{8}$ coke and $\frac{1}{8}$ coal; flux, raw limestone. The addition of a large quantity of coal soon made itself apparent. Compared to the former experiments, the charges were fewer, and the slag became tough. On tapping the furnace, the metal flowed sluggishly, and was fine-grained. By lessening the burden of ore and increasing the temperature of blast as much as possible, endeavors were made to prevent the furnace losing heat; but, however, not with success till the

7th Exp., when burned limestone was used, without, however, changing the other quantities of material in the round. This, again, put the furnace in good working order, and metal was large-grained and very strong.

The fine crystalled metal obtained from the two last experiments was tried at the puddling works at Herminenhutte, and was pronounced of inferior quality; because, owing to great waste in the puddling furnace, the yield was small and of poor quality.

8th Exp. In this experiment burned limestone was used with the raw coal, owing to it having proved itself the most advantageous. The results were quite the same as those obtained under similar circumstances at Antonienhutte and Konigshutte; therefore, after three days, in order to increase the temperature and get the furnace in good working order, the burden was changed to that used in the second experiment. The metal made before the furnace lost heat was large crystalled, and could be used in the foundry; but that made during the latter part of the experi-

Table of Experiments with Raw Coal at Blast Furnaces at Gleiwitz.

No. OF EXPERIMENT.	Average number of rounds in 24 hours.	AVERAGE PROPORTION OF MATERIAL PER 2 TONS OF FUEL.					Percentage of burden.	Produce per round.	PROPORTION OF COKE AND COAL.		Production in 24 hours.	QUANTITY OF MATERIAL CONSUMED PER 100 LBS. OF METAL.						Small coal used for boilers in 24 hours.	Number of tuyeres.	Diameter of nozzle of tuyeres.	Pressure of blast per square inch.
		ORE.			FLUX.							FUEL.		ORE.		FLUX.					
		Brown hematite.	Mill cinder.	Total.	Limestone.	Burned limestone.			Coke.	Raw Coal.		*Coke.	Raw coal.	Brown hematite.	Mill cinder.	Limestone.	Burned limestone.				
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	per cent	Lbs.	Per cent.	Pr. ct.	Lbs.	Tonnen	Tonnen	Lbs.	Lbs.			Ton	No.	In.	Pfd.
Ordinary burden when using coke alone . .	240	550	65	615	252	..	31.00	190.65	100.00	..	45,756	1.049	..	288.44	34.09	132.12	..	15	8	$2\frac{3}{4}$	3
1.....	240	565	65	930	241	..	30.76	193.75	91.67	8.33	46,500	0.946	0.085	291.61	33.54	124.38	..	13	8	$2\frac{3}{4}$	3
2.....	252	590	65	655	250	..	30.50	199.77	83.33	16.67	50,342	0.834	0.166	295.34	32.53	125.14	..	3	8	$2\frac{3}{4}$	3
3.....	252	590	65	655	..	145	30.50	199.77	83.33	16.67	50,342	0.834	0.166	295.34	23.53	..	72.58	..	8	$2\frac{3}{4}$	3
4.....	234	570	65	635	225	..	30.74	195.19	66.67	33.33	45,674	0.683	0.341	292.02	33.30	115.27	..	..	8	$2\frac{3}{4}$	3
5.....	236	570	65	635	..	140	30.40	195.19	66.67	33.33	46,064	0.683	0.341	292.02	33.30	..	71.72	..	8	$2\frac{3}{4}$	3
6.....	190	550	65	615	220	..	31.00	190.65	33.33	66.67	36,223	0.350	0.699	288.44	34.09	123.26	..	..	8	$2\frac{3}{4}$	3
7.....	194	550	65	615	..	135	31.00	190.65	33.33	66.67	36,986	0.350	0.699	288.44	34.09	..	70.81	..	8	$2\frac{3}{4}$	3
8.....	172	550	65	615	..	135	31.00	190.65	..	100.00	32,791	..	1.049	288.44	34.09	..	70.81	..	8	$2\frac{3}{4}$	3

Temperture of blast.	COST PER 100 LBS. OF METAL.																		COST OF MATERIAL.						
	Coke.		Raw Coal		Brown Hematite		Mill Cinder.		Limestone		Burned Limestone		Heating Boilers.		General Cost.			Total.	Name of Material.	Cost.		Cost at Gleiwitz Hutte.		
Deg. C.	Sqr.	Pfund.	Sqr.	Pfund	Sqr.	Pfund	Sqr.	Pfund.	Sqr.	Pfmd.	Sqr.	Pfund	Sqr.	Pfund.	Sqr	Pfund.	Rhil	Sqr.	Pfund		Sqr.	Pfn.	Sqr.	Pfn.	p tonne.
280-300	15	11.96	..	..	9	1.60	1	5.04	2	5.06	..	..	..	4.13	5	10	1	5	1.79	1. Small coal for boiler fire	.	..	10	6	"
280-300	14	5.11	1	7.55	9	2.87	1	4.77	2	3.36	..	..	..	3.52	5	10	1	5	1.18	2. Large coal.....	..	..	19	2	"
280-300	12	8.62	3	2.18	9	4.22	1	4.26	2	3.53	..	..	..	0.75	5	10	1	4	9.56	3. Coke from Zalirzer caking coal..	..	..	15	3	per etr.
300	12	8.62	3	2.18	9	4.22	1	4.26	..	..	3	3.91	..	..	5	10	1	5	9.19	4. Brown hematite.....	..	..	3	2	"
300	10	4.98	6	6.43	9	2.96	1	4.65	2	1.35	..	..	..	..	5	10	1	5	6.37	5. Mill cinder	..	..	4	2	"
300	10	4 98	6	6.43	9	2 96	1	4 65	..	..	3	3.44	..	..	5	10	1	6	8.46	6. Limestone, including 2 pfund for breaking	..	..	1	10	"
300	5	4.05	13	4.77	9	1.60	1	5 04	2	3.11	..	..	..	..	5	10	1	7	4.57	7. Burned limestone, per 100 pfund	..	..	4	7	"
300	5	4.05	13	4.77	9	1 60	1	5.04	..	..	3	2.94	..	..	5	10	1	8	4.40						
300	..	..	20	1 27	9	1 60	1	5.14	..	..	3	2 94	..	..	5	10	1	9	8.85						

The ton referred to in the above table of experiments is a measure equal to 7 1-9th cubic foot Rhinish, or about 240 lbs. coke (Prussian zoll. gewicht).

ment, when the furnace had lost heat, was mottled. It proved unsuitable for puddling. The experiments have proved that, in order to obtain regular work and good yield, such as is obtained when using coke alone, not more than $\frac{1}{7}$ by volume of coal, such as that from the Konig pit, dare be used in working the furnaces at Gleiwitz. That the reason why a larger addition of coal may be made with advantage at Antonienhutte is, that there coal is less gaseous than that from the Konig pit, and, consequently, the loss of heat through coking in the furnace is not so great.

The greater width of throat at Antonienhutte had, no doubt, also a slight influence; at least the great pressure of gas in the narrow throat at Gleiwitz seems to make this suggestion.

The economical results, by far the most important results of the experiments, confirm what was expected, that, notwithstanding the high price of coal, a saving as compared to working with coke alone would be effected in Nos. 1 and 2 experiments, while a larger addition of coal would increase the cost of production.

The saving was effected in Nos. 1 and 2 experiments, through: 1. Less coal and limestone being necessary in the furnace. 2. Through almost no small coal being required to fire the boilers and heat the blast.

The fact that according as the addition of coal increased, the burden consumed did not, but on the contrary decreased, is thus explained: The raw coal, which ought to bear a great burden, has its power to do so more than counterbalanced by the cooling effect in the furnace. On that account, a wide throat necessitates the ore being calcined, in order to balance this loss of heat. It was proved, however, that this did not give an economical result.

The satisfactory results of the second experiment have given encouragement henceforth to charge the Karsten furnace with $\frac{1}{6}$ and $\frac{5}{6}$ coke, which has thus far given satisfaction; but any attempt to increase the addition of coal has always resulted unsatisfactorily. Fine-grained metal made with this mixture of $\frac{5}{6}$ coke and $\frac{1}{6}$ coal is at present being puddled at Herminenhutte, and gives good results. It works regularly, balls neither too fast nor too slowly, and gives, when used alone, faultless merchant iron and at the same time only moderate waste.

In order fully to understand the working of raw coal when white iron was being made, No. 2 furnace at Gleiwitz (Schultz furnace) was experimented upon with $\frac{5}{6}$ coke and $\frac{1}{6}$ coal. Here a higher burden of ore was proved to be practicable; it was difficult, however, to make white metal when the furnace was in good working order; it was mostly mottled, and when the burden of ore was increased, in order to insure a make of white metal, the furnace got out of proper working order. The quality of metal made on this occasion is not in great demand. White iron finds a ready market, and commands a better price than fine-grained grey pig iron. Therefore, so long as these circumstances exist, the Schultz furnace will be more advantageously worked exclusively with coke.

HINTS ON FORGING IRON.

From "Iron."

An interesting "blue book" was published some time since, containing much valuable information given to Government by the most eminent firms in the country. A brief summary thereof may not be devoid of interest and value, as these sources of information are not often applied to by, or accessible to, the general public.

With respect to the best mode of securing from deterioration the store of raw iron, the opinion is expressed that it should be kept under cover and exposed as little as possible to the influence of moisture. The best iron is that which is most frequently worked, or which in the manufacture undergoes the greatest number of processes at a welding heat. But very superior iron, with the exception of charcoal iron, is produced from re-manufactured scrap and old iron; and, in order to insure the most perfect workmanship in this important article, it is submitted that means be afforded in the dockyards for re-manufacturing the whole of the suitable scrap and old iron which arises in the service. In some private establishments this is done with extraordinary care, and the result is a very superior article.

The cleaning of the scrap iron previous to manufacture is recommended to be done in the chain-cable cleaning machine as far as possible. By this means, not only will the scrap iron be perfectly cleaned, but the cleaning of the chain-cable will be facilitated by the increased attrition thus produced.

With reference to the means of producing sound smiths' work, the most fertile sources of defects which from time to time have been experienced are—(1) The original inferior quality of the iron; (2) Improper treatment in the forging; (3) Improper treatment of articles of smiths' work in actual service. With respect to the quality of the iron, that employed in the dockyards is generally of good quality, and only requires due care in its treatment to render the work produced therefrom equal to any legitimate duty required of it. With respect to the second cause of defects, namely, improper treatment in the forging; as this head refers to a very extensive class of defects, it may be proper to regard it, first, with reference to the nature of the forging; and, secondly, to the kind of coal used in the operation.

It being most important that every condition necessary for the operation of welding should be in the highest state of perfection, this requires that the iron should be at the right welding heat, rather than over or under it; so that, if any slight delay or impediment arise in bringing the parts together, there may be, as it were, a surplus of heat to work upon; and next in importance to this is, that as little scoriæ or oxide, or other foreign material, as possible should cling to, or interpose between, the surfaces about to be welded. As the welding of iron is accompanied by its combustion, and by the production of an oxide in a melting state, we must altogether get quit of this interposing material, as, ere the two pieces are laid together, it has a tendency to form as rapidly as it is swept or wiped off. But, very fortunately, in almost every case, if due care be paid to the form and manner in which the surfaces are presented together, the instant the blows are given to the parts in question, the interposing scoria is forced out, and the then perfectly pure surfaces of the welding-hot iron are so brought into intimate contact as to unite together and form one mass. There is no department of the art of forging more important than this, inasmuch as, in the majority of cases of defective welding, it is observed that the defect in question has arisen either from the scoriæ being shut up by means of improper forms of the surfaces, or that it has been insufficiently expressed from between the surfaces, for want of due energy in the blows of the hammer. That great attention should be paid to this is the more important and requisite, inasmuch as, in a great many cases, the system of "dab on" welding is unavoidable in the production of certain pieces of work; and as such "dab on" parts are generally subject to great and unfavorable strain, it is more than usually requisite to adopt the proper precautions, so as to secure the proper expression of the scoriæ, and the intimate union of the surfaces.

Secondly. On the subject of forging, it may be proper to refer to the kind of coal used in that operation. Much evil arises in this process from the risk of viscid and sulphurous scoriæ clinging to the surfaces of the iron, owing to the use of raw or impure coal as the material for the smith's fire. If the coal were of a pure quality, namely, such as contain nothing but carbon and its ordinary bituminous accompaniments, the evil alluded to would be less felt; but as all coal contains, besides earthy matter, more or less of sulphur, a class of evils arises which is of a very serious nature. When we attempt to weld together two pieces of iron which have been heated in a fire formed of very sulphurous coal, not only is the quality of the iron damaged by being rendered brittle, but also its surface becomes covered with a certain substance, which, in a very remarkable degree, destroys that adhesive quality which accompanies iron when at a welding heat. When this evil exists to excess, the parts will not unite, however much they may be hammered. But although such an extreme case as this is not frequent, yet it is a question of degree, and not of existence, so long as raw coal is used. It is therefore advisable for those fires which admit of it, slightly to carbonize the coal in a separate oven previous to use. This is the practice in most private establishments where the quality of the smith's work is a prime object. The practice should be discontinued of making notches in the scarphs of two pieces of iron about to be welded together, as such notches afford a lodgment for scoriæ, etc. Another extremely bad practice should be discontinued, namely, that of throwing a few fresh coals into a

hollow fire on the hot iron, just before the heat is coming out. The use of air-furnaces prevents this.

It is recommended also to abolish cold hammering, unless the articles can afterwards be annealed, and to return all obsolete unserviceable anchors to be worked up in the dockyards, into wrought iron bars, etc., under the steam hammers and rolls. The committee appointed to investigate the several matters relating to iron, etc. (including Mr. James Nasmyth), report that the result of their experiments clearly shows that very heavy strains, even to the extent of the breaking strain (that is equal to the strength of the iron itself,) and this even several times repeated, were found not only not to weaken the iron, but actually to increase its strength by every application. This conclusion is drawn from the following results of the several experiments :—

	Mean Breaking Strain.
1st fracture	33¼ tons.
2d "	35¾ "
3d "	37½ "
4th "	40⅝ "

"These facts," the committee say, "appeared so important, and were so much opposed to the opinion of the best informed persons upon the subject, that in order to prove beyond all question, that the increased strength was due to the repeated previous strains, and not to the diminished length of the bars, we considered it proper to make experiments upon this point; we therefore took several bars of the same kind of iron, and of the same diameter, but varying length from 10 in. to 10 ft., and found they were all equally strong. It may be proper to state the circumstances which usually attend the fracture of iron bars; namely, that considerable heat is evolved at the breaking place, and that the diameter of the bar is everywhere reduced, but particularly so at the place of fraciure ; but it is worthy of remark, that at the second and subsequent fractures of the bars, it generally happened that little or no heat was given out at the place of fracture, and that general diameter of the bar was not again the sensibly reduced, except in some instances, at the place of fracture."

No appreciable difference is caused by the process of galvanizing, as the following abstract of numerous experiments proves. (The breaking strain in tons.)

Size of Iron. Inches.	Galvanized Tin Iron.	Not Galvanized.
1¾	53.375	52 833
1½	39.625	39.375
1 3/16	27.375	27 06
1	19.25	19.25
¾	10.625	10 688
½	4.375	4.312

Such is a brief summary of the report, which was contributed to by information from twenty distinguished firms, and which has been drawn upon only where the information would probably be of general use.

We may say, in conclusion, that some of the results announced by the committee are somewhat remarkable. If they are right, as to increase of strength resulting from the continued application of the breaking strain, what becomes of the modern doctrine of the "fatigue" of metals, and how are we to reconcile therewith the admitted action of the testing machine submitted to the Institute of Naval Architecture in 1872?

PRESIDENTIAL ADDRESS OF I. LOWTHIAN BELL, TO THE MEMBERS OF THE IRON AND STEEL INSTITUTE.

GENTLEMEN,—My distinguished predecessors in this chair have followed the example of presidents in similar institutions to our own, by delivering an address upon their entering upon the functions of their office. Before undertaking a duty thus imposed upon me by custom, allow me, in all sincerity, to tender my very grateful thanks to the members of the Iron and Steel Institute, who have placed me in a position filled successively, and filled so ably, by His Grace the Duke of Devonshire, and by Mr. Bessemer.

We have now reached the fifth year in our history, and I may perhaps be permitted to refer briefly to the amount of success which has attended our efforts in organizing a society calculated to afford to its members opportunities of conferring with each other on matters of mutual interest.

In this country, anterior to the establishment of the Iron and Steel Institute, we, as

manufacturers of iron in its various forms, had little opportunity of communicating in public the results of our own experience, and of comparing those results with the observations of other persons equally interested in their development. As soon, however, as it became clearly apparent that there was an earnest desire among the first, as well as among the succeeding promoters of our society, to cast aside all narrow jealousy, and to add unreservedly individual knowledge to the general stock of information, a great and a steadily increasing wish manifested itself in the minds of iron and steel makers, in all parts of the empire, to be admitted as members. Indeed, this willingness to be enrolled in the ranks of the Iron and Steel Institute has not been confined to the British ironmasters and to those interested in this country in the manufacture or useful application of the metal in its different conditions, but has extended itself to our colleagues in Europe and the United States of America. To all these, in your name, I venture to offer a most cordial welcome, and to invite them to co-operate with us in promoting the common object we have in view.

The actual number of members inscribed upon our roll amounts to 522, to which may be added 65 candidates for election, so that we may now count upon the support of 587 gentlemen all directly interested in the questions we meet to discuss. Looking, however, at the field which ought to furnish us with recruits, I am far from believing that we have reached those limits we may reasonably hope to attain. In this kingdom alone there are at work something like 700 blast furnaces for smelting iron, and about 7,000 puddling furnaces for transforming the metal into its malleable state. Add to the proprietors and officers of higher grade connected with these undertakings, those occupied in our steel works, foundries, engineering and divers manufactories and professions to whom iron is a necessity, and the persons to whom the knowledge we seek to cultivate ought to be an object of the highest moment must be estimated by thousands.

There exist here and there instances of that disregard for scientific inquiry which is a natural consequence of no inconsiderable success in our vocation, effected independently of all philosophical research. With such, practical experience, as it is termed, is the only rule admitted as a guide. But what is practical experience but science of a kind—it is the observation, and, to some extent, the connection of certain facts; science, however, so constituted is often incomplete in its links, its conclusions are frequently erroneous, and a consequence of its application has often been great loss and grievous disappointment.

On the other hand, abstract science, correct as it may be in every step employed in its elaboration, when introduced into the workshop, may be unable to stand the rude but inevitable test of commercial practicability. If so, then all efforts to raise its object to the position of an industrial enterprize must be useless. It is therefore clear that, if we would avoid the failure of what may be designated unscientific practice, or the failure of impracticable science, we must seek to combine commercial intelligence with a knowledge of those natural laws which form the only trustworthy groundwork of the complicated processes in which we are engaged. Now, there cannot be a more convenient method of effecting a sound union between these two great principles than that afforded by such an organization as the Iron and Steel Institute, in which are brought, face to face, men, some distinguished for their practical knowledge, and others equally eminent for their attachment to scientific observation.

Facts, as such, may be completely established, and yet very delusive inferences may be deduced from their existence. Thus, 40 or 50 years ago, it was well known that in winter a blast furnace did more work, and often with less fuel, than it was capable of accomplishing in summer. It was not unreasonable to ascribe this alteration in efficiency of duty to some supposed virtue possessed by cold air in smelting iron, which virtue was less conspicuous when the blast was admitted at warmer temperatures. It was this view of the cause of the difference which led some manufacturers to deny the merit of the hot blast. Now, every one of course knows that a blowing engine supplies a greater weight of air when its volume is condensed by cold, and that, as a rule, it delivers its blast more free from moisture when the temperature of the atmosphere is below the freezing point of water, the presence of the latter occasioning a considerable and useless absorption of heat, and of course a corresponding waste of fuel.

Again, so far back as 1841, Ebelmen

examined and published his researches on the composition of the gases emitted by the blast furnace. These investigations were followed up by others of a similar nature by Bunsen, Playfair, Tunner, and others. The true importance of the assistance rendered by these labors, undertaken by men of science, seems, at the time, to have been disregarded by iron manufacturers. Nevertheless, they contain information of the highest interest in connection with the economy of fuel in the smelting process.

If the founding of the Iron and Steel Institute has not created a desire for accurate knowledge, based on sound scientific investigation, it has done much, by the character of its meetings and discussions, to foster and develop it. In this we have received material help from the labors of our secretaries, Mr. Jones and Professor Forbes. From the former, we have early intelligence of what is being done in the British Iron and Steel trades, as well as of the proceedings of other learned societies, when they embrace matter likely to interest the members of our own. In his periodical report, our foreign secretary gives us an excellent account of the progress of these industries in other nations, which he accompanies by numerous references to scientific discovery and literature extracted from the published works of continental authors. It must be admitted that the cultivation of metallurgical science has been much more industriously pursued abroad than has hitherto been the case in this country, and hence the value of these extracts obtained by the exercise of great labor on the part of Mr. Forbes. Let us now hope that the increasing weight attached by ourselves to scientific aid, may induce our own philosophers to pursue inquiry in directions which, while it affords abundant opportunity for congenial investigation, may also be highly useful and valuable to society at large.

It will be in the recollection of earlier members that at our inaugural meeting our first president gave us an interesting account of the history of the iron manufacture from the remotest times down to the present day. It would be impossible, in the absence of any trustworthy record, to allot, even during the last three centuries, to each nation the proper amount of credit to which it is entitled for aid rendered in advancing this branch of metallurgy. So far, however, as concerns the production of iron, and its application to those purposes which have rendered it a necessity of civilized life, we need not go back beyond 1806, when the production of pig iron in this country did not exceed 260,000 tons.

We have very recently been again warned of the present aspect of foreign competition. It is said that this threatens, as it did ten years ago, if not to extinguish, yet seriously to cripple a trade which has occupied a very honorable and conspicuous position in our manufacturing annals. Doubtless, the progress made in other lands has been more marked during the last 20 or 30 years than in our own case, but the change has arisen from a rapid adaptation of our appliances, and not from any important discoveries abroad. Until, indeed, we are made acquainted with a series of improvements equal to the puddling process, the substitution of the rolling mills for forge hammers, the hot blast, and our last grand achievement of Bessemer steel, we must permit our national pride the luxury of believing that it is to ourselves, more than to any other people, that the world is indebted for the advance which enables it to be furnished with cheap iron. In striving to attain economy in production, our manufacturers have not been insensible to the importance of being able to furnish the metal in which powers of great resistance are not incompatible with comparative lightness. Had this been overlooked, the high speeds of our express trains would have been fraught with danger, marine engines could never have been compressed in the small space they now occupy, and no one would have dreamt of throwing a projectile of 600 or 700 lbs. weight for a distance of five miles from a gun made entirely of English iron.

Recognizing, as we all now do, the value of inductive reasoning, it certainly is a matter of surprise how great the progress has been in the iron industry of this country, made independently of all scientific teaching. This advance has been probably due to the opportunities of experiment which have been afforded by an enormous trade, fostered by great capital and by almost unlimited natural resources. To judge correctly of the nature of the growth, which has culminated in the present wonderful expansion of this branch of manufacture, we should have to arrange alongside of our brilliant successes a list of our costly failures, or of the irrational patents of so-called improvements in the manufac-

ture of iron and of steel. Had we, as a nation, been a little more systematic in our methods of study, it is possible some of the fruitless attempts at improvement made by ourselves might have been avoided, and less time and money lost in endeavors to render assistance to others who had neither science nor practice to guide them.

Leaving our past history, and directing our attention to events as they now are passing before us, there is nothing more certain to arrest it than the extraordinary disturbance in our position as iron manufacturers occasioned by the recent greatly altered value of fuel.

Having regard to the large quantity of coal burnt in producing a railway bar, it is not too much to say that if anything like the former average price of ordinary pig iron, viz., about 60s. per ton, were to prevail, the iron trade of this kingdom would, with fuel at even half its present price, commence to decline. This was exactly what did happen when timber grew scarce, and was worth more for other purposes than that of smelting. Of course, any process of partial extinction as that supposed possible would be very gradual, the weaker districts succumbing in the first instance. The very diminution in the production of iron would of itself liberate so large a quantity of coal as would tend to restore an equilibrium in the price of this element of consumption. This is obvious when it is borne in mind that out of 107½ millions of tons of coal raised in this kingdom in 1869, 32¼ millions were devoted to the manufacture of pig and malleable iron.

In the year 1862, the make of the former, in Great Britain, was close on 4 millions of tons; in 1872, it was probably 6¾ millions of tons. At this rate of increase, in 1882, it ought to reach about 11½ millions of tons, and for this, and the probable extension of malleable ironworks, judging by the experience of 1869, something like 65 million tons of coal might be required. Alongside of this tendency to increase which has marked the history of the iron trade, it is only fair to assume that other sections of British industry would not remain idle in this respect. Under such circumstances, it becomes important that we should consider how far our coalfields would be able to meet any greatly increased demand on their resources for an article which is more or less a necessity for almost every variety of manufacturing enterprise.

It is not my wish to weary you with statistical details, because the erection of new mills in the cotton and woollen districts, the extension of our railways, the substitution of steam for sails in navigation, inform us that the same activity which prevails in the iron trade is also on all sides adding to any difficulty which an inadequate supply of coal must entail upon ourselves.

On all hands it is admitted that the increase in the yield of our collieries has recently been below that of the fresh demands it has had to satisfy. In my opinion, an important addition can and will be made to their present output; but it is very possible that the time is approaching when any extension of manufacturing operations in this country will have to be regulated, not by the requirements of society for their produce, but by the means our coal mines possess of furnishing the fuel required.

It must not, however, be supposed that the recent very rapid rise in the price of coal has to be accepted as presenting any standard by which we can estimate the extent of the actual deficiency. As is well known, a very moderate shortness in the supply instantly makes itself felt in the market, and this shortness happening when almost every description of manufacture was in an unusually active state, the effect on the selling value of coal and coke has assumed a highly exaggerated form. In like manner, the moment the demand falls, or even is expected to fall, a trifle below the powers of production of our collieries, we may expect to experience a very notable diminution in the price of these commodities.

My own impression is, that an addition of less than 5 per cent. to the quantity of coal raised during the past year, would in all probability have sufficed to keep in check the exorbitant prices it has commanded in the market; but in the meantime our own trade owing to the magnitude of its consumption, has upon certain occasions been regarded as the chief cause of the recent and present scarcity. It will, I think, be found on inquiry, that the iron and steel works have not, during 1872, used much more than their usual proportion of the total output, *i. e.*, instead of burning, as in former years, 29 to 30 per cent. of the gross produce of the collieries, the quantity consumed may have reached 33 per cent. of the whole.

However this may be, it behooves us, after

our recent experience, to reflect on our position in the event of a continuance or a recurrence of any great competition for so essential an element in our operations as coal. It is obvious, in such a case, that industry will suffer most into which the cost of fuel enters most largely. Now, roughly, according to the figures in the report of the "Royal Commissioners appointed to inquire into matters relating to coal," every 1,000 tons raised in this kingdom is disposed of as follows:

In paper making and tanning	6
" smelting copper, lead, tin, and zinc	8
" water works	14
" breweries and distilleries	18
" chemical manufactures	19
" railway work	20
" steam navigation	30
" articles of clay and glass, and lime-kilns	31
" textile fabrics, of wool, cotton, silx, flax, and jute	42
" gas works	60
" mining operations	67
" coal exported to foreign countries	92
" general purposes, chiefly steam engines	121
" domestic use	172
" iron and steel works, inclusive of that required for their steam power	300
	1000

Hence it would appear that the iron trade of this country requires for its prosecution as much coal as any two of the largest sources of consumption, and between seven and eight times that of textile fabrics, one of which, alone, viz., cotton, is regarded as the most important in point of money value of all our manufactures.

The mere extent of any industrial undertaking can scarcely be regarded as being detrimental to the national well-being, even although it involves the destruction of the vast weight of coal just mentioned as being set aside for the ironworks of the country. The case, however, is materially altered if it can be proved that the fuel we employ is greatly in excess of that which is really necessary, and beyond that which by actual experience has been proved elsewhere can be made to suffice. An opinion has been expressed in high quarters that the British iron-makers are accountable for a wilful waste of national wealth by their reckless expenditure of coal; indeed, only a month or two ago, a minister of the crown informed the world from his place in Parliament that he had "conversed with an intelligent gentleman connected with the iron trade, who had travelled in France and Germany for the purpose of comparing the different modes of production and manufacture, and no one circumstance struck him so much as the difference between the economical use of coal in France and Germany and its wasteful consumption in this country."

I intend, in the time you have been so good as to place at my disposal, to consider how far we have laid ourselves open to this reflection upon our manufacturing skill and intelligence In thus examining the fuel consumed in some of our processes, and comparing our position in this respect with that of other nations, I propose to avail myself of the opportunity to offer a few observations on some questions connected with the processes themselves, which possess a high degree of interest at the present moment.

The natural starting point in such an inquiry as that contemplated is the blast furnace, because, whatever the ultimate product sought for may be, it is the first step in the routine of our operations; and, secondly, because of the whole quantity of fuel required in the iron trade, it alone absorbs one-half.

In the gradual improvement of this very important item of the ironmaster's plant, this country may be said to stand without a rival; indeed, with the single exception of the use of the waste gases—no doubt a most valuable discovery—every step in the march of amelioration is due to British skill. For more than half a century, after Darby succeeded in introducing Dudley's plan of substituting mineral fuel for charcoal, the blast furnace may be said to have remained in a stationary position. This was the state of affairs when Neilson, 50 years after Darby's time, enabled us gradually to quadruple the make of a furnace and reduce the consumption of coal on the ton of iron to less than one-half of its previous amount. Some 10 or 15 years ago, and about 30 years after the date of Neilson's hot blast patent, the smelters of the North of England, disregarding the failures which had accompanied former attempts at enlargement, added by degrees to the height of their furnaces until it was nearly doubled. At the same time their attention was directed to a further increase in the temperature of the blast employed in the operation. These two improvements effected a saving of fully 35 per cent of the fuel previously consumed, and each furnace was enabled to run 400 tons, instead of half this quantity, per week.

When it is remembered this change was

effected in a new district where there was not a work much above a dozen years old, and that in an incredibly short space of time about 40 furnaces were demolished, and others erected at double their cost, it cannot be maintained with any justice that indifference to the economy of fuel is a reproach that can be laid at our door. This is rendered more conspicuous by the fact that the great outlay in question upon plant was incurred when coke was less than one-third of the price it now commands.

Reduced into figures, it may safely be stated that with the perfect mode of withdrawing and utilizing the gases, and the improvements in the furnace just mentioned, the present make of pig iron in Cleveland is produced with 3½ millions of tons of coal less than would have been needed 15 years ago. This is equivalent to a saving of 45 per cent. of the quantity formerly used.

With such an amount of success as that just alluded to, it is not surprising that furnaces may have been built beyond those dimensions where further economy in fuel becomes a physical impossibility. In like manner it may be proved,—indeed, there are some of us who think it has been proved, that there is a point beyond which it is useless to go in heating the blast. It is, no doubt, within our reach to study those laws in the laboratory of the chemist, which may be supposed to define such limits as those alluded to, but after all, the problems they involve are too complicated to render satisfactory anything short of an actual appeal to the blast furnace itself. We are indebted to the enterprise of some of our members that in spite of the great expense attending such gigantic experiments, this appeal has been made, and it would be wrong to omit acknowledging the services which Messrs. Cowper, Charles Cochrane, and Thomas Whitwell have rendered in the course of these very important inquiries.

In order to settle the still contested point as to the value of an excessive amount of heat being introduced along with the blast, too much attention cannot be paid in endeavoring to ascertain the precise mode of action exercised by heated air. This discovery of the hot blast by Neilson, was the result of what Dr. Percy styles a "lucky hit." In this view of the invention I entirely concur; because its author had made no investigations to justify the expectation that 1 cwt. of fuel burnt in his stoves would save 5 cwt. of coke burnt in the furnace. This result is the less to be expected when we remember that of the heat evolved by the combustion of the 1 cwt. of coal in the hot air apparatus, not one-third reaches the tuyeres.

If for the introduction of this remarkable discovery we owe nothing to experimental research or philosophical inquiry, it is perhaps equally true that the modes adopted in accounting for its most unexpected influence have been nearly as unscientific. The refrigerating effect of a large volume of cold air admitted into the hearth of the furnace —the higher temperature generally of its contents—a more speedy union of incandescent carbon with heated than with cold oxygen and the reduction of the ore nearer the crucible, have all been given as explanations of the apparently mysterious action of the hot blast. These various conclusions appear to have been arrived at without, so far as I can learn, any experimental proof having been given in their support.

I hope you will not regard me as abusing the privilege I enjoy of addressing you from this chair, if I venture to give my reasons for dissenting from opinions formed by authorities, who, with the single exception of practical experience, have been so much better qualified than myself to explain the theory of the hot blast.

That the action of heated air is not dependent on any of the conditions just enumerated, was, in my judgment, made apparent as early as 1834, by facts mentioned by M. Dufrenoy. This gentleman, who does not appear to have continued the inquiry by the light afforded by his own observations, was sent over to this country by the French Government to ascertain whether the accounts given of Neilson's discovery were to be relied on. Dufrenoy mentions the circumstance that, although there was no exaggeration in the statements respecting the use of the hot blast in Scotland, its application at Guerche, in France, had not been accompanied by any notable advantage. Along with this, we have the then admitted fact in this country that there was never realized in Wales, by the use of heated air, much above one-half the saving effected in smelting the minerals of Scotland. It was also ascertained that in foundry cupolas and in refineries its use was not

productive of any economy worthy of the name.

The explanation, which appears to me sufficient to account for the phenomena which manifest themselves in connection with the use of hot blast, is that it is *time* as well as heat, which determines the difference of action between it and that of cold air. In addition to the heat units contained in the blast, and which in effect are precisely equivalent to a similar quantity of heat evolved by the combustion of the fuel at the tuyeres, there is an increase in the period of exposure of the ore to the reducing current of gas, and this it is which, in my opinion, accounts for the remainder of the saving. In the case of the Guerche ore, 25 cwt. of fuel was able to smelt a ton of iron, whereas for some ores in England, as, for example, those of Shropshire, 40 cwt. of coke was needed. The ores of both localities are about of the same richness, and require for fusion about the same quantity of limestone, cold blast being used in each case. I ascribe this difference in the results obtained to the circumstance that different ores, as has been repeatedly proved, are reducible at very different rates of speed, and in the two instances under consideration, that of England was by far the least susceptible of deoxidation. A necessary consequence of this dissimilarity is that the Shropshire ironstone demands a longer exposure to the current of reducing gas than that smelted at Guerche. This longer exposure is secured by the generation of a larger volume of carbonic oxide for every ton of iron made, in other words, by the use of more fuel. Now it might be supposed that an equally beneficial effect could be commanded by allowing the furnace to drive more slowly; but experience teaches us that no advantage accrues from this mode of treatment. The reason of this is, that heat, as well as chemical action, is involved in the operation, and if we seek to prolong exposure by a diminution in the speed at which the heat-intercepting solids pass downwards, the temperature of the escaping gases instantly rises and a loss ensues, which neutralizes, or more than neutralizes, the gain due to an increased duration of exposure.

An extended period of contact between the reducing gases and the ore may be arrived at in another way without interfering at all with the powers the descending solids possess of intercepting the heat which is being carried forward in the contrary direction. To achieve this, all that is required is to retain the original rate of velocity at which the solid materials travel downwards, and make the column through which they have to pass so much the longer. This was tried at Lilleshall, and it is very remarkable that a ton of iron is there smelted with cold air in furnaces 71 ft. high, with exactly the same quantity of fuel as is consumed in furnaces about 20 ft. lower, but fed with hot blast.

But it may be asked, how the mere heating of the blast extends the time allowed for reduction and heat interception. This arises as follows:—A certain quantity of heat is essential for the general purposes of the furnace, which heat, in one working with cold blast, is derived exclusively from the fuel, and the quantity of carbon required to be burnt to afford the necessary calorific effect determines the quantity of gas, and of course determines its velocity upwards. If, however, a portion of the necessary heat is generated not by combustion of carbon in the furnace, but is conveyed into the hearth by the blast, we have the same calorific power as before, but contained in a smaller volume of gaseous matter, and the reduction of volume at the same time lessens the speed of the current towards the throat; in other words, permits a longer sojourn of the gas in the furnace.

We have then, in the higher furnace fed with cold air, a portion of the reducing gas, carbonic oxide, becoming as far as the nature of the operation will permit, charged with oxygen which it abstracts in small quantities from a larger number of portions of iron oxide contained in the longer column. In the shorter furnace driven with hot air, each portion of carbonic oxide becomes similarly charged with oxygen, by passing over fewer portions of iron oxide, but remaining longer in contact with each.

Now, the inquiry which such an explanation as the foregoing prompts, is whether a furnace could have its height so increased as to dispense with heating the air altogether, and thus save the fuel used in the hot blast apparatus. Approximately, two-thirds or three-fourths of the quantity of heat contained in the air when at about 900 deg. F., is found in the gases as they leave the furnace. If, then, we could so arrange matters as to reduce the

temperature of these gases to that of the atmosphere, we might diminish the heat of the blast to something like 350 deg. F. It seems pretty certain, however, that a large proportion of the heat found in the gases is due to chemical action going on so near the top of the furnace, that it is highly improbable much change can be effected in the way suggested. This means, looking at the price of fuel used in the furnace, and that employed in the hot air stoves, that it will be found advantageous to continue to heat the air to something above 800 deg. F.

The extent to which the reducing gas (carbonic oxide) can take up oxygen, offers an impassable barrier to diminishing the fuel used in the furnace beyond a certain point. What this precise minimum point is, may be a subject of some doubt, but in my opinion we are very close upon it when we are using about 21 cwt. of Durham coke, in smelting a ton of foundry iron from the usual run of Cleveland ore.

When it is stated that in practice we often come within five per cent. of this theoretical quantity, the ironmasters of this country cannot be justly accused with wasting fuel, at all events in the blast furnace. On the other hand, I apprehend that we, in common with our friends in Germany, France, and elsewhere, are not sufficiently mindful of the heat capable of being afforded by our waste gases. This loss arises chiefly from the unnecessarily high temperature at which, as a rule, the products of their combustion are permitted to escape into the atmosphere, and might, in a great measure, be suppressed by the use of apparatus of increased power. Of course, this is a question to be decided upon commercial considerations alone, for if the additional size of boilers or other apparatus, in connection with our smelting establishments, involved a greater money value in interest and repairs than the saving of fuel was worth, we must be content to suffer the waste. At the same time it must be remembered that the relation between the saving and its cost is a very fluctuating one, and that which was impracticable, commercially speaking, with coal at one price, becomes imperatively necessary when its value is quadrupled, as has happened very recently.

The proper fuel of the blast furnace is coke, and it is easy to prove that the act of coking, as it is usually performed, entails a great sacrifice of heat. This is due to the combustion of about one-half the volatile constituents of coal being sufficient to effect the expulsion of the whole. In the County of Durham, we are now beginning to follow the example set us by the Belgian ironmasters by using the surplus of heat as a motive power, which with us is applied to the general purposes of the colliery.

The use of raw coal in the blast furnace involves the expenditure of a certain quantity of additional fuel in order to gasify the hydrocarbons, but this loss Mr. Ferrie has succeeded in rendering unnecesary by his so-called self coking furnace, which has been described and discussed in our Transactions.

With the less important exception of the heat obtained by burning the escaping gases of the blast furnace, in which there arises an admitted waste, it seems as if we are justified in believing that the smelting process is being carried on in England with almost as small an amount of fuel as theory indicates to be possible. When, however, we leave this department of the ironmaker's art and enter that devoted to the manufacture of the metal in its malleable form, we have no alternative but to concede that, in this country, as well as in every iron-producing community, a great waste of heat is very apparent. The conversion of pig into wrought iron may be said to be exclusively performed in the reverberatory furnace, as the only one which hitherto has been capable of doing the required duty. In this small structure a small quantity of material is exposed at one time, with a view to avoid waste of metal, and the consequence is an immense waste of heat, which makes its escape up the chimney, as well as by great dispersion from radiation and convection from the thin walls of the furnace. So great is the loss from these causes, that Professor Krans, of Louvain, estimates that in an ordinary mill furnace the iron does not absorb more than 7 per cent. of the heat emitted by the coal employed. True it is, the plan, originally a French one, I believe, of raising steam by heat, formerly carried off by the chimneys of our forges and mills, has been extensively introduced into this country. Even then, according to some recent trials I have had made, the loss is nearly 30 per cent. of that due to the fuel consumed, which is about three times the quantity required for

determining the draught of the chimney itself.

When the products of combustion from a reverberatory furnace of the ordinary type enter direct into the flue, the heat conveyed away is probably not under double that which is lost when they are utilized for steam purposes, *i.e.*, 60 per cent. of the calorific power of the fuel is wasted from this cause. Mr. Siemens avoids, in a very great measure, this loss, by the use of his so-called regenerative system, in which the gases are cooled down to about 400 deg. F., instead of escaping at above 2,000 deg. In order to re-convey this heat into the furnace, the fuel is employed in the form of gas, which, along with the air required for its combustion, arrive at the working bed at a very high temperature, where they unite under very favorable conditions. The use, however, of the coal in a gaseous form involves a loss of about 30 per cent. of its heating power, but such is the advantage derived from the regenerators that the effective duty obtained from a Siemens furnace is, according to M. Krans, more than twice that afforded by one of the old form.

When a moderately high temperature only is required, and the waste heat can be profitably employed as a source of steam, it is not clear that there is any gain in using Mr. Siemens' more complicated apparatus, but the great value of the invention consists in the intense heat it enables us to command—in the cleanness of its flame, and the readiness with which the nature of the flame can be altered by the admission of a greater or less relative quantity of inflammable gas. These last mentioned peculiarities are probably destined to raise this furnace to a position of great importance in iron metallurgy, as I shall shortly have occasion to show.

In the year 1856, there was read, at the Cheltenham meeting of the British Association, a paper, which, during the late fabulous prices of coal, would have been received with peculiar interest by the iron trade. The title it bore was, "On the manufacture of iron and steel without fuel." It is difficult to say whether science or art was more perplexed at this announcement by your late president. The former appears to have thought it prudent to remain silent at all events in the Transactions of the British Association; for all the notice there bestowed on Mr. Bessemer's discovery is the bare mention of the title of his communication. Art was less reticent, for I remember the ridicule with which the proposal was received, because the process, as you know, involved the keeping a mass of malleable iron liquid, the heat being obtained by blowing cold air through molten pig. They who were incredulous overlooked a fact they must have observed many times in the ordinary refinery, in which, towards the end of the operation, an intense temperature is maintained by the action of the blast on the metal, and this increment of heat is independent of the coke used in the process. Correct as Mr. Bessemer's title of his invention may be in ordinary language, it is certainly not so from a scientific point of view, the fuel in reality consisting of the carbon, silicon, and about 10 per cent. of the iron under treatment. If men of science hesitated to pronounce on the merits of the invention at the time, they and we were equally in the dark as to the cause of failure in Mr. Bessemer's first attempts. Dr. Abel analyzed some iron made by this method from a very pure kind of pig, and I will venture to say, except in the laboratory, a purer, or as pure a specimen of the metal never was heard of. It contained only a minute trace of carbon, no silicon, a mere trace of phosphorus and manganese, and only .02 per cent. of sulphur. Nevertheless, the wrought iron, as well as the steel made according to Mr. Bessemer's original plan, were simply worthless. In this difficulty a ray of scientific truth, brought to light 100 years before, came to the rescue. Bergmann was one of the earliest philosophers who discarded all theory, and introduced into chemistry that process of analysis which is the indispensable antecedent of scientific system. This Swedish experimenter had ascertained the existence of manganese in the iron of that country, and connected its presence with suitability for steel purposes. My friend, the late Josiah Marshall Heath, was led, I understand, in consequence, to try the effect of introducing this metal into ordinary cast steel with the most useful results.

In smelting certain German ores containing manganese there had been produced for many years a certain variety of iron known as Spiegeleisen, which contains a varying quantity of the former metal. Mr. Robert Forester Mushet, conceived that the addition of this substance into the Bessemer converter might remove the defects of steel

made by the new process for the same reasons that Heath's addition of manganese had been serviceable in the steel pot. In this hope he was not disappointed, and by this simple, but important modification of Mr. Bessemer's original idea, we now have 400,000 tons annually produced in this country, of Bessemer steel or iron, for it is difficult to say to which division it properly belongs. Notwithstanding this, and notwithstanding the possibility of other methods hereafter contesting with it its present position of supremacy, no one can hesitate to admit that Mr. Bessemer's invention constituted and will continue to constitute a most important era in the history of the iron trade, both as regards the ingenuity of the apparatus employed, and as regards the opportunity it has afforded the world, for the time, of applying cheap steel in cases where iron had hitherto been exclusively made use of.

Up to the period of Mr. Bessemer's invention, the quantity of malleable iron which had been seen simultaneously in a liquid state was extremely small. As a mere scientific fact, the announcement that 5 tons of this substance could be melted under such extraordinary conditions as he described, was one well calculated to excite feelings of the utmost surprise; and had there been no other method discovered of commanding the necessary temperature on a large and economical scale, the Bessemer converter must have remained the only means of procuring cast steel at a cheap rate. This faculty, however, is now divided with the Siemens furnace, and for some years past, this form of apparatus has been employed in the so-called Siemens-Martin process, consisting of melting a mixture of pig and wrought iron together in such proportions as to form steel or steel-grained iron. This mode of manufacture, however, has the inconvenience of requiring the partial intervention of the puddling process, which is costly and is entirely avoided by Mr. Bessemer's plan.

More recently, at the Siemens Steel Works, at Landore, the regenerative furnace has been put in requisition to produce steel by a remarkably simple mode of procedure, indicated 150 years ago by Reaumur, and, subsequently, by Hassenfratz and others. Pig iron of suitable quality is fused in the furnace itself, and, when at an intense temperature, iron ore of the purer descriptions of oxides is added. A reaction takes place, by which the pig iron loses its silicon and carbon, and the ore its oxygen, the iron from both remaining in the metallic form. Thus, that which is lost in weight by the former, is compensated for by the iron supplied by the oxide; in other words, steel is obtained equal to the weight of pig iron used. To the melted wrought iron Spiegel is added, and the product run out into ingots, which are treated for subsequent stages of manufacture in the usual way, *i. e.*, hammered, and then rolled into rails, etc. The fuel consumed, I am informed, does not exceed that employed for driving the machinery, melting the pig, and keeping the converters hot in the Bessemer process.

Admirably as the blast furnace performs its work, in respect to avoiding unnecessary waste of fuel, keeping in view the nature of the operation, and admirably as it discharges the duty, economically speaking, of separating the earthy impurities of the ore from the metal, there are doubtless certain disadvantages connected with the present mode of smelting iron. If an atmosphere of gas of a highly reducing nature has to be maintained in the interior of the blast furnace, and I am correct in supposing that this is only to be commanded by permitting about two-thirds of the carbon burnt to escape as carbonic oxide, we are compelled to submit to a sacrifice of 47 per cent. of the calorific power of the fuel actually consumed at the tuyeres. Again, the temperature which is produced near the hearth when the pig iron and slag are liquefied, is so intense that silica and the earthy phosphates are deoxidized, and the resulting silicon and phosphorus, along with sulphur and occasionally other ingredients, are incorporated with and injure the metal. The presence of these substances in the pig can of course be avoided by using materials free from them, but in the product of the blast furnace there is one inevitable ingredient, viz., carbon. This element is dissolved in the iron at the high heat which prevails near the tuyeres, and when wrought iron has to be obtained it has to be got rid of by the laborious operation at the puddling furnace. As is well known, the mere reduction of the iron oxide requires no very extraordinary elevation of temperature.

To avoid the evil consequences which appear inseparable from the process of smelting as at present conducted, Mr. Siemens has lately described a method of obtaining wrought iron direct, by exposing the ore

with coal in a revolving furnace heated by his regenerative system. The heat is kept at such a point that neither carbon, phosphorus, silicon, nor other impurities, he alleges, are to be detected in the iron obtained. The difficulties to be apprehended in this system are that, in burning the fuel so as to command an approach to its full calorific effect, there may be re-oxidation of the reduced iron by carbonic acid, at even the lower temperature to which it is exposed. Secondly, there is the inconvenience, if poorer ores are used, of dealing in a comparatively small piece of apparatus with a large quantity of slag, which is apt to dissolve any unreduced oxide. It is not my intention, however, to anticipate the discussion which will arise on the paper on the subject, which Mr. Siemens has kindly promised to read at the meeting. It may appear incredible that a principle, which was extinguished by the blast furnace, when the latter was a very puny instrument comparatively, should be raised from the dead as it were, and inflict a mortal blow on the reputation of an antagonist, which, in the meantime, has made such immense strides in general efficiency. Let it not, however, be taken for granted that there is necessarily any sound argument in such premises, because experience constantly teaches us that far less variations than those which obtain between the Catalan furnace and Mr. Siemens's proposal may make all the difference between success and failure.

Mr. Siemens attaches much importance to this method of procuring malleable iron, obtained, he expects, at less cost than pig; because, by means of it, steel can be made with a less quantity of the dearer pig iron than when the carbon, etc., of the latter is removed by iron ore.

Before leaving the question of steel, I would again call attention to a subject mentioned by the Duke of Devonshire in his address, viz: the Whitworth plan of removing air cells from fluid steel by means of extreme compression, estimated at 20 tons on the sq. in. Sir Joseph Whitworth has favored me with a perusal of a work in course of publication, in which are given highly instructive photographic views of sections of steel ingots, cooled both under and without pressure. Steel so compressed has been found, without further treatment, to bear fully double the tensile strain of the best iron made in this country.

Soon after Mr. Bessemer's first experiments, it was found that certain qualities of pig iron were utterly unfit for his process, and in this way scientific inquiries became inevitable in order to discover the cause. The chief source of trouble was traced to the presence of phosphorus, and next followed sulphur. It was then proved that if the former exceeded .06 or .07 per cent., the iron containing it had to be condemned and rejected. We all know that when any epidemic disease breaks out, many specifics against its attack are recommended to the public upon unimpeachable authority. So it was, and so indeed it is with phosphorus. No sooner was its influence for evil decided, than innumerable cures were offered, and high praise awarded to many of the plans for ridding iron more completely of this enemy, than could be effected in the puddling furnace. It is, I fear, to be lamented, that little, if any, marked progress has been made as yet in this direction. Many of the processes must have been the result of guess work, which only required to be heard to be dismissed from serious consideration. In the meantime, we must hope that as our knowledge of the chemical relations between iron and other substances advances, this great problem may be satisfactorily solved. This, however, is not likely to be accomplished by mere speculation, but will require at our hands long and patient study.

The rules of the Iron and Steel Institute forbid all discussion having for its object the regulation of the price of labor. If I now venture to allude to the subject, it is with no intention of transgressing our laws, but because, connected with it, there are certain social questions which are pressing themselves upon the attention of manufacturers as well as upon that of statesmen and others. In an article like a railway bar, it will be found that, within 5s. a ton payable to the owner of the minerals, the cost is almost exclusively the product of wages. Under these circumstances the labor question is one which, whether we will or not, forces itself upon us, and, in the event of our being disadvantageously placed in respect to it, our only hope is in the comparative advantages we enjoy in the abundance of our raw materials.

Although, as I will endeavor to prove, our position at the present moment is far from being a favorable one in respect to the cost of labor, it is not now that we have,

as a whole, to apprehend any danger. The unusually high prices of coal and iron have enabled us to agree to demands from our men which hitherto have only amounted to a reduction of the profits of the capitalist. Practically, however, it may be assumed that the manufacturer, working his own coal and ironstone, cannot to-day sell railway bars with any advantage at less than 50 per cent. above the average price of the last half-dozen years.

Regarded as an entirety, the iron trade of this country is in an unusually elevated position; but there are certain facts connected with it which seem, even now, to demand serious reflection. The effect of the great increase in the value of labor, and the demands maintained by foreign countries for the mere raw materials of coal and pig iron, are already making themselves felt. Our malleable ironworks, involving a much larger amount of human manipulation than either mining or the manufacture of pig iron, can no longer be said to participate in the general prosperity, in proof of which 300 puddling furnaces, it is said, have been recently laid idle in the North of England.

This rise, in some instances, is due to a simple increase in the rates paid in the various departments without any reduction in the hours of labor. In others, along with a large augmentation in the prices paid, the workman has reduced his hours of attendance, and by so much has reduced the productive power of the country. It is impossible for any section of industry to carry on its business regardless of the health of the operatives engaged in its prosecution, and no one can regret a change should the result be an improvement in the physical condition of the workmen. If a partial shortening of the hours of work is followed by any substantial benefit to the laboring classes, we must prepare ourselves for its general adoption, and, no doubt, the example set by this country will in time be followed by the rest of the world. In the meantime, both masters and men, in their respective spheres, must take care that we do not fall behind in the race with other nations, whose competition we have to meet in the markets of the world. In one form, it is true, foreign countries may be said to have preceded us in this matter, for although the actual hours of attendance are longer than our own, the amount of physical exertion is occasionally less by reason of more men being engaged in the duties to be performed.

During a journey undertaken about five years ago, with Mr. John Lancaster, through a great number of mines and ironworks in France, Belgium, and Prussia, we came to the following conclusions. In many instances the ironmasters on this side of the water were paying at that time nearly double the wages given abroad for similar work. Notwithstanding this—owing to the magnitude of our ironworks, to the superiority of our arrangements for economizing labor, and to the greater amount of work done by individuals—the nett disadvantage was reduced to a difference in favor of the foreign makers of about 25 per cent. The extent of this drawback, however, has been greatly magnified by the recent alterations in the scale of wages paid in this kingdom; for while ours will probably average 50 per cent. on the old rates, theirs do not exceed 10 to 20 per cent., so that in point of relative position, labor costing on the Continent 20s., will here amount to 30s. or 35s. Since the visit made in company with Mr. Lancaster, I have examined ironworks in Austria, Norway, Sweden, Italy, and Spain, and, to the best of my belief, their general condition in respect to labor resembled that already described. Hence, so far as I know, they are now not less favorably situated in comparison with Great Britain, than the other districts seen upon the former occasion. In by far the greater number of European States, according to our present information, there is a limit to any rapid increase in the production of iron. Of ore, in some of them at least, there is an ample supply. Near Bilbao are mountains partly composed of brown hematite, and the valley of the Moselle has a deposit of oolitic ironstone, richer and more cheaply wrought than that of Cleveland. The impediment which stands in the way of any great extension of the Continental iron trade is—coal, for if all the produce of the remainder of Europe for the last year were added together, it would scarcely exceed the half of that raised in the United Kingdom. So far as the actual cost of extraction is concerned, I make no doubt that at the present day in France, Prussia, and Belgium, coal, on an average, can be as cheaply delivered at the pit's mouth as it is in this country. The united output, however, of the mines

of France and Belgium, would not suffice to keep our ironworks in activity, while that of Prussia would, after performing this duty, leave but little to spare. Competing, of course, for this necessity of all manufactures are many other sources of consumption, which have probably tended to keep down the total production of pig iron by our neighbors to about one-half that of our own.

If, then, we have to apprehend the advent of a powerful rival in the iron trade, it is not, unless new coal discoveries are made, the old world of Europe we have to fear, but the immense and undoubted powers possessed by the Western hemisphere. In ores of the finest descriptions, the resources of the United States are unlimited, while in coal our own wealth is, in comparison, but poverty. In many cases, the relative geographical situation of these minerals is not unfavorable; in short, there is apparently but one bar to a boundless production of iron in the New World—that of human hands to manufacture it. The stream of emigrants, however, constantly flowing from this side of the Atlantic, would seem to enable our friends on the other to advance at a rate unknown even in this country; for according to the "Statistical Report of the National Association of Iron Manufacturers" of the United States, no less than 107 furnaces were erected there in 1872, which is equal to an increase of 18 per cent. of those in blast in 1870. In the matter of skill, everyone who has had the opportunity of inspecting the American ironworks concurs in reporting that their development is quite in keeping with the advantages Nature has conferred upon that highly-favored country.

Intimately associated with the cost of labor is the question of its substitution by mechanical means, and in the hope of reducing the expense and increasing the output of coal, the employment of machines for hewing has, of late, received great attention. Here, as well as in working ironstone in such beds as those of North Yorkshire, we may hope to see human labor partly superseded by the use of machinery, but it is problematical whether the cost of either can be reduced thereby to the extent of 6d. per ton at the present rate of miners' wages. At the blast furnaces it is difficult to see how the use of steam power can with advantage be more extensively introduced than it is at the present moment.

It cannot be otherwise than gratifying to any one interested in the iron trade of this country to witness the immense advance which has been effected in the power and excellence of the machinery in our forges and mills. In the forge we have the old imperfect helve and squeezer giving place to the ponderous hammer of Nasmyth, thundering down its blows on an anvil grasped by a block weighing sometimes a couple of hundred tons. In the mill we have the rolls and their accompaniments so admirably contrived that the production of a plate of 15 tons is an object of almost less difficulty than was one of 5 cwt. in the recollection of many whom I have the honor of addressing.

In the malleable iron department, however, the subject which commands most attention at the present moment is the hope we all entertain of seeing the arduous operation of puddling by hand superseded by the aid of machinery. The efforts of Mr. Menelaus at Dowlais, as you all know, have been continued in America, where labor is even more costly than it is with us, and one modification of his ideas has been adopted by Mr. Danks, and subsequently another by Mr. Spencer, at West Hartlepool. The Commission appointed under the auspices of this Institute reported so favorably on the furnace of the former gentleman that several have been erected in the neighborhood of Middlesbro'; hence, time alone is now wanting to enable us to judge with our own eyes of the correctness of the opinions expressed by our Commissioners sent to the United States.

I have now, in conclusion, to express the deep obligation I am under for your attention to various topics, which it would be difficult to invest with novelty, to an audience so conversant as this assembly with the manufacture of iron and steel. The moment I began to apply my mind to the preparation of an address, I felt it was hopeless to attempt more than to embody, in a consecutive form, those ideas which appear to me to demand careful consideration at the present moment. This I have endeavored to do, in order that we might encourage each other to persevere in that search after truth which cannot fail to be productive of good in the grand and honorable division of human industry, to which it is the pride and felicity of the members of this Institute to belong.

THEORY OF THE EXPLOSION OF DETONATING COMPOUNDS.

By P. CHAMPION and H. PELLET.

From the "Comptes Rendus," through "American Chemist."

In his remarkable researches on compressed gun-cotton and nitro-glycerine, Professor Abel has advanced the hypothesis that the explosion of detonating compounds can only take place on condition of exciting in these compounds a mechanical action of a peculiar kind depending on their properties and their constitution. In accordance with this theory the heat developed by the explosion of the priming cannot be sufficient to produce the molecular change necessary to instantaneous decomposition. Moreover, Mr. Abel has supported this theory by a certain number of experimental proofs.

It seemed interesting to us to go farther in this direction and to show by more direct experiments that heat and the impact of gases are not concerned in this action, except in special cases, in which these influences themselves occasion a vibratory movement which cannot be obtained by other means.

FIRST EXPERIMENT.

We joined together by a strip of paper two tubes of strong glass, having an entire length of 2.4 metres and an inside diameter of 13 millimetres. We introduced into each extremity about .03 grammes of iodide of nitrogen placed in a paper boat. The explosion, occasioned at one end by friction, or by the aid of a heated iron wire, caused immediately that of the iodide placed at the other extremity. By increasing gradually the length of the tube we are able to cause the detonation at a distance of 7 metres, for the same weight of iodide of nitrogen.

Mr. Barbe, in his work on dynamite, describes a similar experiment made by him with dynamite, but in which he attributes the explosion to the pressure of the air caused by the expansion of the gas. It was now to be ascertained if the impact of the air did not take part in that result.

For this purpose we placed in the tube at 50 centimetres from one of the extremities, a little pendulum made of a pith ball suspended by a filament of silk, and caused the most remote portion of iodide to detonate. The slight shock given to the pendulum was the same as that which was obtained upon blowing into the tube with the mouth. By diminishing the proportion of iodide we may even prevent the pendulum from striking the upper wall except at the instant when the explosion occurs. If, in this experiment, we chance to separate the two tubes by a space of 5 or 6 millimetres, the explosion by influence no longer manifests itself, except upon increasing much the proportion of the explosive compound. It is not even necessary to introduce within the tube the iodide which we make detonate directly. A drop of nitro-glycerine, a few centigrammes of fulminate of mercury, or of nitro-erythrite, placed upon an anvil before the opening of the tube, and the explosion of which we cause by a blow, have the same effect upon the iodide.

SECOND EXPERIMENT.

We placed the iodide of nitrogen, moistened, upon the strings of a double bass viol, securing it with a bit of gold-beater's skin; as soon as the iodide attained the requisite degree of dryness, we made the strings vibrate by means of the bow. In no case did the iodide placed on the two lowest toned strings detonate. With regard to that which was placed on the string yielding the highest tone one stroke of the bow was sufficient in most cases to produce its explosion.

If we stretched the preceding string so as to give *si* natural, no effect was produced by the influence of the vibrations; but, upon raising the tone of any note, immediately the detonation takes place. We can deduce from thence the inferior limit of the number of necessary vibrations. This number, according to our calculations, is about 60. We can also, by bringing into unison the two most distant strings, effect by the vibration of the lower toned the explosion of the iodide placed upon the other.

The trial on the bass strings requires a few precautions. If the gold-beater's skin has not been sufficiently stretched in the damp state, the iodide, which by the drying is reduced in bulk, shakes about between the membrane and the string, and finally detonates under the influence of the shock produced by the vibrations of the string;

but in that case, which is very rare, the vibrations must be prolonged a definite time. It was not possible for us to determine the superior limit. The same experiments made by means of a violin and an alto, with the able assistance of Mr. Grenier, have always witnessed the detonation of the iodide even on placing it lowest on the parts of the strings which bind the bridge to the body of the violin; the shriller tone, provided it has sufficient intensity, always producing the detonation.

It is not necessary here to consider the modes and the ventres; their influence is destroyed by the amplitude which it is necessary to give to the vibrations in order to produce the explosion with the bass strings.

THIRD EXPERIMENT.

The vibrations produced by metallic plates seem to act like those of stringed instruments.

The following trial was made with two Chinese tamtams, one having a diameter of 56 centimetres and producing very deep tones; the other having a diameter of 47 centimetres and giving higher and metallic tones. On each of these we placed the iodide of nitrogen, secured by a membrane at the centre, at the circumference, and at an intermediate part. The instrument was put into vibration by means of a tampon, similar to that which the Chinese use. The instrument which gave forth the deeper tones had no influence upon the iodide, while the other produced the explosion when the vibrations had acquired sufficient amplitude.

FOURTH EXPERIMENT.

We took two parabolic mirrors having a diameter of 50 centimetres and separated from one another by a space of 2.5 metres. At one of the foci opposite to the mirror, we placed a fragment of paper on which was placed a few centigrammes of iodide of nitrogen, secured by a piece of gold-beater's skin. Between the two mirrors we placed a similar paper serving for an indicator, and at the other focus we made a large drop of nitro-glycerine detonate. We effected thus the explosion of the iodide placed in the focus without influencing the indicator. The same experiment can be made with a very small quantity of nitro-glycerine, by replacing the paper, on which we arranged the iodide, by a membrane stretched over an opening 2 or 3 centimetres square, made in a piece of pasteboard. We cover over the explosive compound with a bit of damp gold-beater's skin, which, by drying, secures fast the iodide and prevents the shocks to which it would be subjected by the vibration of the membrane.

We greatly increase in this manner the sensibility of the apparatus; so much so, that if we exceed the necessary quantity of nitro-glycerine, the indicator itself explodes.

We can replace the nitro-glycerine by fulminate of mercury, or by a small charge of powder introduced into a gun and to which we apply the fire directly. We can obtain the same result with the iodide of nitrogen on condition of making about 1 gramme of this compound detonate. We employed by preference nitro-glycerine because of the less inconvenience which it presents. But in these experiments it may be inferred that the heat produced by the detonation of the nitro-glycerine when concentrated at the other focus is sufficient to cause the explosion of the iodide of nitrogen.

According to the memoir of M. Berthelot, 1 kilogramme of nitro-glycerine detonating in a confined space affords 19,700,000 units of heat; while powder, burning in free air, gives only 644,000 heat units. The quantity of nitro-glycerine necessary to produce the detonation of the iodide of nitrogen under the conditions we have named, is .03 gramme and represents 591 units of heat (admitting that the detonation by a shock corresponds to that which takes place in a confined space).

The quantity of powder required to furnish the same number of units of heat is 0.9 gramme. We then tried to burn 1 gramme of gunpowder at one of the foci of the mirrors. There was no result, and it was necessary to use from 8 to 10 grammes of the powder in order to produce the heat necessary to the explosion of the iodide of nitrogen placed at the other focus.

We had to take care to ignite the powder a little below the focus of the reflector. Without this precaution we lost a notable quantity of the heat produced and the explosion of the iodide becomes uncertain. We were also able to reach the same conclusions in regard to the influence of heat by arranging the foregoing experiment as follows:

The two mirrors placed at the same distance were carefully covered over with soot.

At one of the foci we placed the iodide of nitrogen, and at the other 10 grammes of powder, which we ignited directly. There was no result, the blackened surface absorbing the greater part of the heat developed. By substituting for the powder .03 gramme of nitro-glycerine, the detonation of the iodide again occurred as before, without seeming to be influenced by the blackened surfaces. If, however, we remove the soot and brighten the mirrors, the same amount of powder in every instance, produced the explosion of the iodide.

From the experiments which we have now mentioned, we think that we may conclude that the explosion of detonating compounds should be attributed to a special vibratory movement which varies according to their constitution and their properties, and which may operate independently of heat and the impact of the gases produced by the explosion of the priming.

We are indebted to the kind suggestions of M. Guilemin for having selected, out of the extensive class of explosive compounds, iodide of nitrogen, which, by its sensibility, is so well adapted for these delicate experiments.

TORSIONAL RESISTANCE OF MATERIALS DETERMINED BY A NEW APPARATUS WITH AUTOMATIC REGISTRY.

By Prof. R. H. THURSTON.

From "Journal Franklin Institute."

While the classes of the Stevens Institute of Technology were recently engaged in their revision of coefficients, as given by various authorities on strength of materials, the difficulty of determining how far the differences noted were due to errors of observation, and how far to variation in the quality of the materials used, suggested to the writer the advisability of obtaining an apparatus which should make its own record. This could readily be done by so constructing it that a curve might be automatically registered at each test, which should represent all circumstances of the experiment.

Such an automatic registry would evidently yield more reliable and instructive information in regard to the circumstances of distortion and fracture than could any system of personal observation.

Representing the magnitude of the distorting stress at every instant, and under every degree of distortion of the material, up to the limit of elasticity or even to the point of rupture, and exhibiting also the corresponding alteration of form at every point, the pencilled curve would be a record from which might be deduced the coefficients of elasticity, strength and resilience, as well as the laws governing the relations of the distorting forces to the resistance of the material.

A simple but effective machine was therefore designed and constructed, which accomplishes satisfactorily the desired result, and this machine, as planned by the writer and constructed by Messrs. Hawkins & Wales, instrument makers to the Institute, is shown in Fig. 1.

As here arranged, it is intended for experiments on the torsion of materials. Its

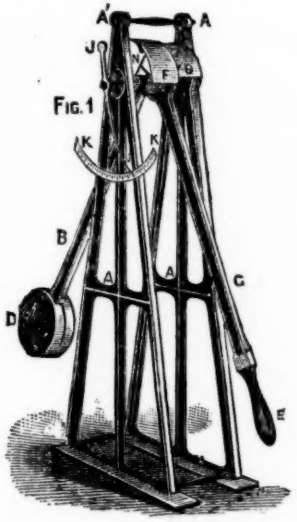


Fig. 1

modifications, for the purpose of experimenting upon transverse strength, will be described in a subsequent paper, in which will be given the results of that series of experiments.

In the figure, the frame, A A, A′ A′, supports two suspended arms, C E, B D, which swing about independent axes in the same line. The arm B carries at its extremity a weight, D, and the arm C has a handle, E, by which it is moved. The axes of these arms are designed as shown in Fig. 2, each

FIG. 2

having a rectangular recess at L and at M, which receive each an end of the test piece, which is squared to fit as shown in Figs. 3 and 4.

The frame, A′ A′, carries a guide curve, F, of such form that its ordinates are proportional to the twisting moments exerted by the weighted arm, B D, while swinging

FIG. 3

through the arc to which the corresponding abscissas are proportional. A pencil holder, I, bears against this guide curve, and, being carried by the weighted arm, is thrown forward, as that arm swings out under the action of the force producing torsion, which force is transmitted through the test piece.

FIG. 4

The arm, C E, carries a table, G, and the pencil, I, therefore, traces upon the paper, which is clamped upon it, a curve, the ordinates of which are proportional to the torsional moments, while its abscissas represent the relative motion of the two arms, and, consequently, the amount of torsion to which the test piece has been subjected.

The curves thus described, of which the accompanying plate exhibits a number, present in a very legible and convenient, as well as reliable, form, all the results of the experiments, of which they are the respective records.

The pointer, J, traversing the arc, K K, is arranged as a maximum hand, and affords a useful check upon the automatic record of maximum strength.

The plate represents the results of average experiments made upon a considerable number of varieties of wood, the test pieces of the form shown in Fig. 3 being used. The diameter of the neck of each piece was seven-eighths ($\frac{7}{8}$) of an inch.

This diameter happened to be that best adapted to use in this machine. A larger size was found, frequently, to yield by the destruction of lateral cohesion, the square head peeling, leaving a prolongation of the cylindrical portion, instead of twisting off in the neck. The size is convenient, also, in consequence of the fact that the coefficient of ultimate strength for the standard diameter of one inch is obtained, with a close approximation to exactness, by simply multiplying the twisting moment for each piece by 1.5.

These curves exhibit the relative stiffness, strength and resilience of the woods tested very perfectly. The inclination of the straight line, forming the first portion of each diagram, from the vertical is a measure of stiffness; the height of the maximum ordinate indicates the ultimate strength; the point at which deviation from this straight line commences, determines the limit of elasticity, and the area included within each diagram is proportional to the torsional resilience of the test piece.

The fact that the commencement is, in each case, almost a perfectly straight line, is well exhibited in the curve, *a a a*, of locust, where the horizontal scale is purposely magnified, justifies the usual assumption that, up to the limit of elasticity, Hooke's law is correct, and that the angle of torsion is proportional to the twisting moment.

The short curve of small radius, noticed at the foot of the straight portion of each line, is produced by the slight yielding of the test piece by crushing, where it is grasped by the machine, which yielding continues until a firm hold has been secured.

It will be observed that, in most cases, the torsional resistance increases with the total angle of torsion up to a maximum, then, passing the limit of elasticity, it drops off more or less rapidly, returning finally to zero. In the brittle woods, the fall takes place suddenly, while, in the tougher and more elastic varieties, the resistance decreases very slowly, in some cases vanish-

ing only after the test piece has been twisted through a very large angle.

In the case of black walnut, 6, 6, 6; locust, 11, 11, 11, and, in a still more remarkable manner in that of hickory, 10, 10, 10, a striking peculiarity is exhibited, which is one of the most interesting and unanticipated developments of this series of experiments. In these curves the resistance increases with the amount of torsion, until a maximum is reached; the line then drops to a point considerably below, and thence again *rises* and passes another maximum, which in the case of hickory, is only reached after a torsion of 75 deg. The resisting moment there becomes considerably greater than at the limit of elasticity.

This striking peculiarity was shown, by carefully repeated experiment, to be due to the fact that, in those woods in which it was noticed, the lateral cohesion seemed much less in proportion to the longitudinal strength than in other varieties. Watching the process of yielding under stress, it could be seen, by close observation, that, in the examples now referred to, the first maximum was passed at the instant when, the lateral cohesion of the fibres being overcome, they slipped upon each other, and the bundle of, then, loose fibres readily yielding, the curve dropped until, by lateral crowding, further movement was checked, and the resistance again rose until the second maximum was reached. Here yielding again commenced, this time by the breaking of the fibres under longitudinal stress, —under that component of torsional stress which takes a direction parallel with that of the fibres in their new positions. In these cases rupture seems never to occur by true shearing in the transverse plane. The fibres part, one after another, the exterior ones breaking first, under a tensile stress.

The following varieties of wood have been subjected to torsional fracture, and the curves obtained are shown in the plate which illustrates this article:

1. White pine (*pinus strobus*).
2. S. yellow pine (*pinus australis*) sap wood.
3. " " " " heart wood.
4. Black spruce (*abies nigra*).
5. Ash (*fraxinus Americana*).
6. Black walnut (*juglans nigra*).
7. Red cedar (*juniperis Virginianus*).
8. Spanish mahogany (*Swietenia mahogani*).
9. White oak (*quercus alba*).
10. Hickory (*juglans alba*).
11. Locust (*Robinia pseudo-acacia*).
12. Chestnut (*castanea esca*).

The curves, the *fac-similes* of which are given in the plate, exhibit well the relative values of the materials tested for the various purposes for which they may be applied.

White pine, 1, 1, 1, yields quite rapidly as the torsional moment increases, and the considerable inclination of the line from the vertical indicates its deficiency in stiffness. It soon reaches the limit of elasticity, and the diagram exhibits the maximum strength of the test piece, 15¼ foot-pounds. Passing the limit of elasticity and the maximum moment of resistance almost simultaneously, its resisting power decreases rapidly, and with tolerable uniformity, until, at "a total angle of torsion" of 130 deg., it is twisted completely off. The area comprised within the curve is comparatively small, and it is thus shown to have little resilience.

Yellow pine, in accordance with our already well established ideas of its properties, is found by an examination of its curve, 2, 2, 2, 3, 3, 3, to have much greater stiffness, strength and resilience. The sap wood, 2, 2, 2, is equally stiff, in the examples tested, with the heart wood, 3, 3, 3, 3, but sooner passes its limit of elasticity, the former circumstance being quite opposed to the preconceived ideas of the writer. Notwithstanding the comparatively low position occupied by the pines in our list, they are excellent materials, the yellow varieties particularly, for general purposes. Our comparison is made with specimens of equal size, and the important fact of the exceptional lightness of these woods is nowhere brought to our notice by these tests.

Spruce, 4, 4, 4, 4, is less stiff than white pine, even, but possesses greater strength and resilience, its moment of resistance reaching 18 foot-pounds and twisting through a total angle of torsion of 200 deg.

Ash, 5, 5, 5, 5, seems to be weaker and less tough than is generally supposed; it is possible that the specimens tested were over seasoned. Its most striking peculiarity is its very rapid loss of strength after passing its limit of elasticity.

Black walnut, 6, 6, 6, 6, of the excellent quality and good condition, as regards seasoning, of the samples tried, is very stiff, strong and resilient, and is but little inferior to oak. Its resisting moment reaches 35 foot-pounds, and one specimen reaches a total angle of torsion of 220 deg.

Red cedar, 7, 7, 7, 7, is stiff, but brittle, and

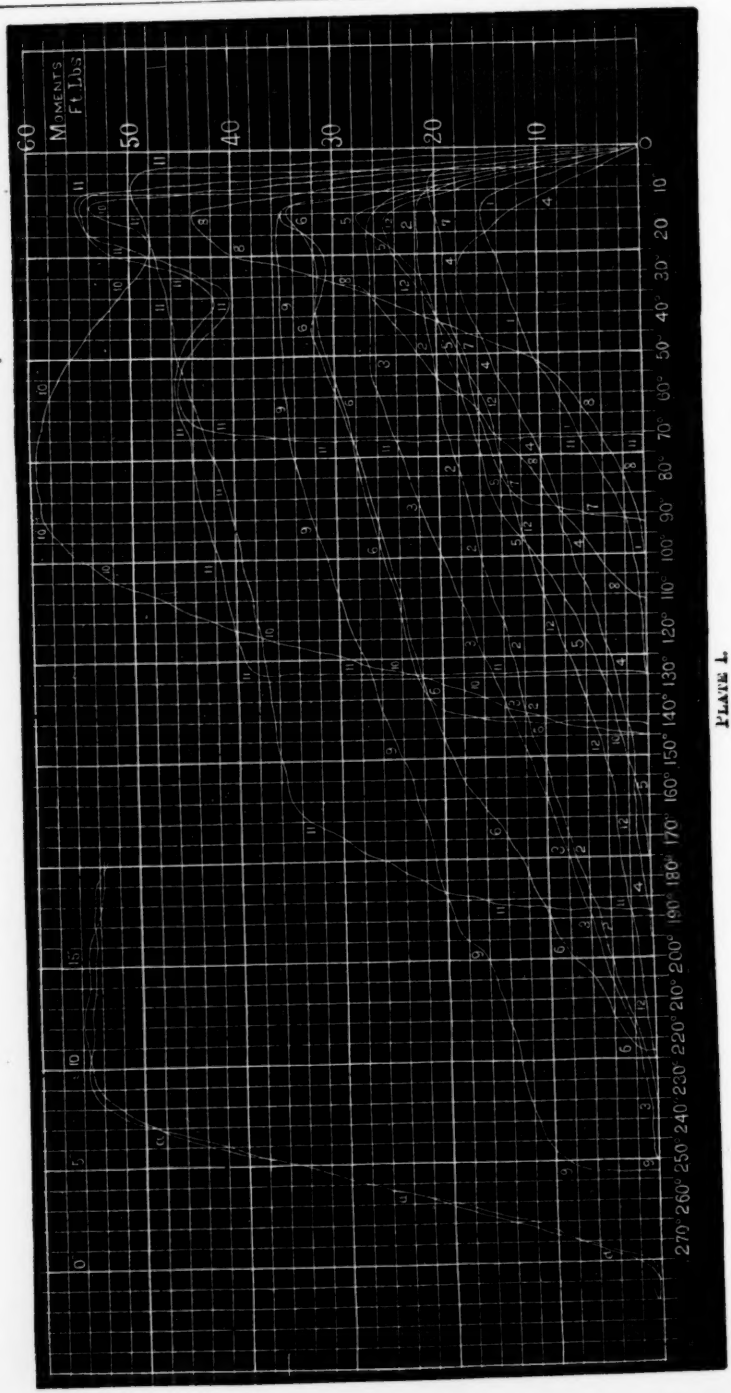

Moments Ft Lbs
60
50
40
30
20
10
0
10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150° 160° 170° 180° 190° 200° 210° 220° 230° 240° 250° 260° 270°

PLATE I.

loses all power of resistance after twisting through an angle of 92 deg. A torsional moment of 20 foot-pounds only produces a total angle of torsion of 5 deg.

Spanish mahogany, 8, 8, 8, 8, is very stiff and strong. It is deficient in toughness and resilience, losing its power of resistance very rapidly after passing the limit of elasticity.

White oak, 9, 9, 9, 9, has less torsional strength than either good mahogany, locust or hickory, but is remarkable for its wonderful toughness. It passes its limit of elasticity at 15 deg., but loses its resisting power very slowly indeed. We find the latter almost unimpaired until it has been subject to a torsion of 70 deg.; it only yielded completely at 253 deg.

Millwrights are evidently perfectly correct in holding this wood in high esteem for strength, toughness, and power of resisting heavy shocks and strains.

Hickory, 10, 10, 10, 10, exhibits, in its curve, the remarkable pair of *maxima* already referred to, and has, apparently the highest ultimate torsional strength, combined with unusual stiffness and considerable resilience. Its moment of resistance to torsion reaches a maximum of 58 foot pounds.

Locust, 11, 11, 11, 11, has greater stiffness than any other wood in our list, and stands next to hickory in strength; it is, also very resilient. Three diagrams are given, each of which possesses its own peculiarities. One specimen is only twisted through a total angle of torsion of 4 deg. by a torsional moment of 48 foot-pounds.

Where more than one curve is given for the same wood, it is a fact worth noticing that the stiffness and ultimate strength are usually very nearly equal, and that the difference between the several specimens becomes marked, if at all, in their degree of toughness.

In the formula for torsional strength, $P a = C d^3$, the curves give values of C, as follows:

1. White pine	25
2. Yellow pine, sap	35
3. " " heart	40
4. Spruce	30
5. Ash	43
6. Black walnut	55
7. Red cedar	32
8. Spanish mahogany	65
9. Oak	53
10. Hickory	85
11. Locust	80
12. Chestnut	35

Determining relative stiffness by obtaining values of the ratio of twisting moment to the total angle of torsion, we obtain the following:

1. White pine	1.00
2. Yellow pine, sap	2.25
3. " " heart	2.25
4. Spruce	0.67
5. Ash	1.87
6. Black walnut	2.63
7. Red cedar	4.00
8. Spanish mahogany	3.00
9. Oak	2.53
10. Hickory	4.15
11. Locust	5.50
12. Chestnut	1.60

Taking the well established value for oak as a standard, we deduce the following values for the coefficient to be used in the formula,

$$\theta = \frac{2 P a}{G \pi r^4} = \frac{\text{Total angle of torsion.}}{\text{Length of part twisted.}}$$

1. White pine	220,000
2. Yellow pine, sap	495,000
3. " " heart	495,000
4. Spruce	211,000
5. Ash	410,000
6. Black walnut	582,000
7. Red cedar	890,000
8. Spanish mahogany	660,000
9. Oak	570,000
10. Hickory	910,000
11. Locust	1,225,000
12. Chestnut	355,000

Finally, by measuring the areas of the several curves, we deduce the following values for relative resilience, white pine being taken as the standard:

The work done in twisting off these specimens is found to have relative values as follows:

1. White pine	1 00
2. Yellow pine, sap	3 01
3. " " heart	3.87
4. Spruce	1.50
5. Ash	2.25
6. Black walnut	5.00; 3.95
7. Red cedar	1.61
8. Spanish mahogany	2.25; 1.65
9. Oak	6.60
10. Hickory	6.90
11. Locust	7.65; 5.85; 3.20
12. Chestnut	2.40

The values of coefficients, as given, will be checked by additional experiments upon test pieces of the form shown in Fig. 4, carefully turned to a diameter of $\frac{3}{4}$ in., and of a length, in the neck, of 1 in.

Coefficients for metals will also be given in a later communication.

STRAINS OF SHIPS IN EXCEPTIONAL POSITIONS ON SHORE.

From "Naval Science."

In former articles we have considered the unequal distribution of weight and support in ships, and the consequent strains in still water and at sea. Our investigations, laid before the Royal Society, extended to cases of ships exceptionally strained when launched or grounded, and these we now proceed to give.

Although exceptional, these strains undoubtedly occur; and their effect may be, as we shall show, more severe than that of any of the statical strains to which approximations have been made. Preceding writers have recognized this fact to some extent, but no author has done so much as Sir W. Fairbairn towards giving quantitative expressions to these exceptional strains.

Bouguer, Romme, and other early writers had a very clear conception of the principal causes of launching-strains. They call attention to the fact that in all, or nearly all, launches the ship's bow or stern is water-borne before the other end has left the launching-ways, and that this cannot be prevented altogether even when the ways are extended further out into the water than is customary. Some of them go so far as to urge the policy of building ships in dock in order to avoid these strains, and support their opinion by statements of the large amount of "breakage" that takes place when a ship is set afloat for the first time from a slip-way. Others combat this opinion, and show by actual examples that ships built in dock also break when they are floated, although the breakage is not always so considerable as when ships are launched; so that the severity of the strains due to launching cannot be estimated simply by the amount of breakage. The latter opinion is undoubtedly the correct one; and the breakage recorded for wood ships when launched may be regarded as due in part to what is termed the ships's "settling" in her new position afloat—that is, to her reaching such a condition as to make her powers of resistance balance the bending-moments due to the unequal distribution of the weight and buoyancy. In part, however, the breakage is undoubtedly due to the dynamical strains connected with launching; and although we cannot separate the effects produced by these two causes, we may very properly regard the amount of the breakage as to some extent a measure of the relation between the strength of the structure and the strains brought upon it. We will pass over the facts respecting the breakage in the older classes of wood ships, and confine our attention to modern wood ships. Speaking of merchant vessels, Mr. Grantham says:* "It is the general custom with builders to leave the gangways of the bulwarks in modern ships unfinished, lest the hull should so much alter in form by settling in launching that the rails would not again fit their places; and no builder would willingly copper a vessel when new, but rather allow her first to find her own position in the water, as she would then be less liable to wrinkle the sheets." In wood-built ships of war there is also a considerable amount of breakage, as the following facts will show: Our finest screw line-of-battle ships, of which the length was about 260 ft., broke, on the average, about 2 in., some ships proving weaker than others, and the breakage in one case (that of the Gibraltar) amounting to 4 in. on a length of 200 ft. Our finest screw frigates, which are 300 ft. long, broke from 3 to 4 in.; the Galatea, 280 ft. long, broke 3 in. Shorter ships, of course, usually broke less than these long fine ships. Iron ships, we need hardly say, display very little change of form or breakage when launched, the character of the materials and fastenings used in their construction being so much less yielding than those employed in wood ships, that they resist more successfully strains of equal intensity.

The severest strains connected with the launching of ships are, however, those which occasionally result from partial launches. The well-known case of the early iron ship Prince of Wales illustrates this statement. Owing to an accident to the launching-gear, she was left for some time with her bow resting on the edge of a wharf and her stern supported by the water—in fact, suspended by the extremities; but although so severely strained no breakage took place. Another case in point is found in the wood line-of-battle ship Cæsar, which stopped on the launching-ways at Pembroke Yard in 1853, and remained for seventeen days

* At page 92 of his work on "Iron Shipbuilding."

with about 64 ft. of the stern unsupported by ground-ways. The result was that the stern dropped about 2 ft. in a length of 90 ft.

A similar but more recent case of stoppage in launching is that of the iron-clad frigate Northumberland, which, in March, 1866, stopped with about 52 ft. of the after part unsupported, and remained in that position for thirty days. The weight of the unsupported part may be roughly estimated at 440 tons, and the moment of this weight about the aftermost point of support at 11,700 foot-tons. At the corresponding station in the Minotaur, when afloat in still water, the bending moment is about 9,200 foot-tons, and when supported on the crest of a wave of her own length, the bending moment is about 12,000 foot-tons. Now the Northumberland, although a sister ship to the Minotaur, has had her disposition of armor altered to the central-battery-and belt system, and by this means rather more than 100 tons weight of armor and backing have been removed on the 52 ft. of length from the stern forwards. The effect of this may be fairly assumed to be a reduction of the still-water bending moments at the station in question to about 7,000 foot-tons, and of the bending moments on the wave to 10,000 foot-tons; and hence it follows that the strains resulting from the stoppage in launching in her case were slightly severer than even the strains corresponding to the exceptional position afloat which we have considered. It is proper to add, however, that they were purely statical strains and acted only in one direction, whereas the strains of waves are, as we have seen, constantly changing in character and intensity, and are therefore very much more trying to the structure. The result of careful observations showed, however, that there was scarcely any change of form in this iron-built ship, the maximum amount of breakage being $\frac{7}{16}$ in. only in a length of 342 ft., and this becoming reduced to $\frac{5}{16}$ in. when the ship was floated.

The very various positions which ships occupy when they ground may all be supposed to lie between the position where the only support is found at the middle of the length, and that where there are supports only at the extremities. Mr. Fairbairn has chosen these extreme positions as those by which the provision of longitudinal strength in a ship should be regulated; and while we cannot entirely agree with this choice, on account of the fact that such positions are never occupied except by a few ships, and by them only in consequence of accidents, we are prepared to admit that there are cases on record which show that such positions may be occupied. Ships have, for example, grounded on rocky bottoms and on causeways, and have been left by the tide with their ends unsupported; and others have grounded in such a manner as to be supported at the extremities only. Under these circumstances it may be well, therefore, to attempt an approximation to the limiting values of the strains incidental to the extreme positions of support ashore, and to compare them with the statical strains which have been calculated for ships at sea.

The most severe strains to which a ship aground can be subjected are those incidental to support at the bow and stern only. In this position the heavy-weighted amidship portion, of course, tends to make the ship sag; and, as it is a very simple mechanical problem to determine the amounts of the upward pressures at the points of support, as well as the weights of the various portions of the ship between the points of support, it is possible to calculate the shearing forces and the bending moments at various stations by a method similar to that previously used for ships afloat. The graphical method of representing shearing forces and bending moments might also be applied to this case were it considered necessary; but this has not been done, on account of the fact that we are principally interested in determining an approximate value for the maximum bending strain, and therefore care but little about the other values, which have no practical importance. Before giving quantitative examples, taken from actual ships, of the maximum sagging strains that may occur in this position, it will be only proper to call attention also to the obviously great increase in the maximum shearing forces which a ship then experiences. Roughly speaking, we may say that one-half a ship's weight is taken at the bow, and the other half at the stern when the middle is unsupported; so that near the points of support the shearing force is approximately one-half the ship's weight. In preceding investigations it has been shown that, for still water, the shearing force has an approximate maximum value of $\frac{1}{2}\frac{1}{2}$ part of the total weight; and that for support on a wave crest the shearing force

probably does not exceed ¼ part of the total weight; hence the above-mentioned fact, as to the increase of shearing strains in a ship ashore, becomes obvious.

The quantitative examples, which have been chosen to illustrate the maximum strains incidental to suspension by the ends only, are based upon the three typical ships previously considered—viz., the Minotaur, the Bellerophon, and the Victoria and Albert. As the result of calculations made for the Minotaur, it has been found that the centre of gravity of the ship, when fully laden, is 210 ft. from the bow, and that when she rests upon the extremities the upward pressure at the bow equals 4,925 tons, while that at the stern equals 4,975 tons. These quantities obviously give the limiting values for the shearing forces experienced by the ship. Next, as to the maximum bending moment which will be experienced by the transverse section of the ship that contains her centre of gravity. Other calculations have been made which show that the centres of gravity of the two parts into which the ship is divided by the transverse section of maximum bending moment are respectively 85 ft. before and 81 ft. abaft this section. Hence, starting from the fore end, we have—

Maximum bending moment
= moment of upward pressure at the bow, minus the moment of the weight of the fore part of the ship.
= 4,925 tons × 210 feet − 4,830 tons × 85 feet.
= 579,300 foot-tons (in round numbers); or about
= displacement in tons × ¼th of the length in feet.

In preceding investigations it has been shown that the approximate maximum bending (hogging) moments for this ship are for still water 45,000 foot-tons, and for support on a wave-crest 140,300 foot-tons, while in a wave-hollow the maximum sagging-moment amounts to 74,000 foot-tons. These figures speak for themselves, and illustrate the large increase in the bending-moments caused by the exceptional supports. The increase in the maximum shearing force, from 450 tons in still water, 1,365 tons on the wave-crest, and 695 tons in a wave-hollow, to 4,975 tons when the ship is ashore, is no less striking.

The Bellerophon furnishes our second example. By means of calculations similar to those made for the Minotaur, it has been found that the transverse section passing through the centre of gravity of the whole ship is about 144 ft. from the bow and 156 ft. from the stern, and that the centres of gravity of the parts of the ship before and abaft this section are distant from it 54 ft. and 64 ft. respectively. The weights of these parts are respectively 3,825 tons and 3,225 tons, and the upward pressures at the bow and stern being respectively 3,666 tons and 3,384 tons, we have

Maximum bending moment
= 3,666 tons × 144 feet − 3,825 tons × 54 feet.
= 321,400 foot-tons (in round numbers); or about
= displacement in tons × ¼th of the length in feet.

It has been previously shown that the approximate maximum bending (hogging) moments experienced by this vessel are 12,000 foot-tons for still water, and 43,600 foot-tons for a wave-crest, while the maximum sagging-moment in a wave-hollow is 48,800 foot-tons. The shearing forces have also been found to have the following approximate maximum values:—In still water 210 tons, on a wave-crest 555 tons, and in a wave-hollow 640 tons, while aground it equals 3,666 tons. The comparative conditions of strain of the ship under these different circumstances can be fairly determined by comparing these figures. It is also interesting to remark the different manner in which changes of the attendant circumstances affect the strains of the two classes of iron-clads represented by the Minotaur and the Bellerophon. The reader can trace these for himself; we would simply call attention to the fact that, when aground and supported at the extremities, the maximum bending-moments bear very nearly the same proportions to the products of the lengths and displacements, notwithstanding the very different distribution of the weight in the two ships. This similarity is mainly due to the fact that the centres of gravity of the fore and after bodies in the two ships are very nearly the same part of the length of these bodies distant from the bow and stern. For example, in the Minotaur the centre of gravity of the fore body is 116 ft. distant from the bow, and the fore body is 201 ft. long, these quantities being very nearly in the ratio of 3 to 5; while in the Bellerophon the centre of gravity is 90 ft. from the bow, and the length of the fore body is

144 ft., the ratio between these quantities being nearly the same as before.

Our third example is drawn from the Victoria and Albert, in which ship the centre of gravity is about 157 ft. from the bow and 143 ft. from the stern. When supported at the extremities only, the bow sustains a pressure of about 1,120 tons, and the stern of 1,230 tons; and the centres of gravity of the two parts, into which the ship is divided by the transverse section containing her centre of gravity, are respectively 60 ft. before and 46 ft. abaft this section. Hence we obtain by the same method as before:—

Maximum bending moment
— 1,120 tons × 157 feet − 1,020 tons × 60 feet.
— 114,700 foot-tons (in round numbers); or about
— displacement in tons × $\frac{1}{6}$th of the length in feet.

The approximate maximum bending-moments previously determined for this ship are, for still water 5,080 foot-tons, on a wave-crest 16,400 foot-tons, in a wave-hollow 31,000 foot-tons; the approximate maximum shearing forces under the same circumstances are respectively 140 tons, 220 tons, and 395 tons. When ashore the maximum shearing force is, of course, 1,230 tons. By comparing this ship with the Bellerophon and Minotaur, it will be seen that the maximum sagging-moment bears a larger ratio to the product of the displacement by the length than it does in the two iron-clads. This is due to the fact, already illustrated, of the greater concentration of weights at the centre of the paddle-wheel steamship.

These three examples afford us the means of approximating to the limiting values of the shearing forces and bending-moments of ships supported at the extremities only, and from them we obtain the following limits. For shearing-forces the maximum lies between one-half and three-fifths of the displacement, and for bending-moments between one-seventh and one-sixth of the product of the displacement by the length. These are, of course, to be regarded simply as *limiting* values; in practice they can scarcely occur, because no ship is likely to rest at the extremities only without having moderate base of support. The amount of the strains actually experienced would depend, obviously, upon the length of the base of support and its greater or less nearness to the bow and stern.

When a ship ashore rests upon a middle support and has her ends unsupported, which is the other extreme position she can occupy, she is, as we have said, less severely strained than when resting on the ends only, the reason for this fact being that the heavy weights carried in the amidship portion are comparatively close to the point of support in one case, whereas in the other they are much more distant. The greatest difference in strains should consequently be looked for in ships having very concentrated weights amidships; and it is interesting to remark that while such a concentration has been shown to be beneficial in reducing most of the principal strains experienced by ships afloat, it is the cause of the increase in sagging strains in ships ashore. A ship having her weights uniformly distributed throughout the length would be subject when supported at the middle only, to hogging moments equalling in amount the sagging moments incidental to support at the extremities. Actual ships, however, have not anything like a uniform distribution of weights, and the greatest weights are usually found near the middle. In spite of the increase in the severest exceptional strains thus caused, however, it cannot be doubted that the ordinary distribution of the weight is beyond comparison better than uniform distribution would be; for its beneficial effect, in reducing strains in ships afloat, is continually called into play, while the other effect is seldom produced.

In order to show the relative magnitude of the classes of exceptional strains in ships ashore, we will again take the three typical ships and give a few quantitative results. The only explanation required of the method we shall follow is, that when a ship is supported on a single point, vertically below her centre of gravity, the maximum shearing force will equal the weight of either the fore or the after body, and the maximum bending moment will equal the product of the weight of one of these bodies by the distance of its centre of gravity from the point of support. The previous investigations therefore supply all the *data* required for the further calculations.

In the Minotaur the after body is the heavier, and its weight, 5,070 tons, constitutes the maximum shearing force. The product of this weight by the distance of the centre of gravity of the after body from the transverse plane passing through the

centre of gravity of the whole ship, 81 ft., gives us:

Maximum hogging moment
= 5,070 tons × 81 feet.
410,600 foot-tons (in round numbers); or about.
= displacement in tons × $\frac{1}{10}$th of the length in feet.

The maximum shearing force is a little greater in this case than in the case of support at the ends; and the maximum hogging moment is considerably over two-thirds the maximum sagging moment. It may also be interesting to compare these exceptional hogging strains with the strains incidental to support on a wave crest. These are: Hogging moment 140,300 foot-tons, shearing force 1,365 tons.

The Bellerophon is divided into two parts by the transverse plane containing her centre of gravity, such that the foremost or heavier part weighs 3,825 tons, and has its centre of gravity 54 ft. before the plane of division. The maximum shearing force for support at the middle is therefore 3,825 tons, a little greater than in the previous position, and we have

Maximum hogging moment
= 3,825 tons × 54 feet.
= 206,500 foot-tons (in round numbers); or about
= displacement × $\frac{1}{10}$th of the length.

This moment is considerably under two-thirds of the maximum sagging moment previously found for this ship; and we have in this fact an illustration of the statement made above respecting the difference existing between the exceptional hogging and sagging strains in ships with concentrated weights amidships, as compared with other ships. In the Victoria and Albert we should expect to find a more striking illustration, and we really do so. Her after body is heavier than the fore body, and its weight, 1,330 tons, constitutes the maximum shearing force, while the centre of gravity is 46 ft. abaft the centre of gravity of the whole ship. Hence we have

Maximum hogging moment
= 1,330 tons × 46 feet.
= 61,200 foot-tons (in round numbers); or about
= displacement × $\frac{1}{12}$th of the length.

The maximum sagging moment in this ship is therefore not very much less than double the maximum hogging moment experienced by the ship ashore; when compared with the Minotaur, the case of the Victoria and Albert appears still more striking.

These three examples lead to the conclusion that the limiting maximum values of the strains experienced by ships supported only at the middle may be fixed as follows: For shearing forces between one-half and two-thirds of the displacement; for bending moments between one-ninth and one-eleventh of the product of the displacement by the length. As in the other extreme position of support, these limits can never be approached closely in actual ships, on account of the more or less extended base of support which is pretty certain to be found under ships ashore.

In order to facilitate a comparison between the various strains experienced by the three typical ships under different circumstances, the following tabular statement of the results arrived at in this article, and in our preceding articles in "Naval Science" on the Strains of Ships, is given:

Table of Maximum Bending moments and Shearing forces determined for the Minotaur, Bellerophon, and Victoria and Albert.

	Minotaur.		Bellerophon.		Victoria and Albert.	
	Shearing force.	Bending moment.	Shearing force.	Bending moment.	Shearing force.	Bending moment.
	Displacement.	Displacement ×length.	Displacement.	Displacement ×length.	Displacement.	Displacement. ×length.
In still water	$\frac{1}{2\frac{1}{2}}$	$\frac{1}{3\frac{1}{3}}$	$\frac{1}{3\frac{1}{3}}$	$\frac{1}{7\frac{1}{2}}$	$\frac{1}{1\frac{1}{6}}$	$\frac{1}{7\frac{1}{3}}$
On a wave crest	$\frac{1}{2}$	$\frac{1}{2\frac{2}{3}}$	$\frac{1}{1\frac{1}{3}}$	$\frac{2}{9\frac{1}{7}}$	$\frac{1}{1\frac{1}{7}}$	$\frac{1}{4\frac{1}{3}}$
In a wave-hollow	$\frac{1}{1\frac{1}{7}}$	$\frac{1}{6\frac{1}{3}}$	$\frac{1}{1\frac{1}{7}}$	$\frac{1}{4\frac{1}{3}}$	$\frac{1}{2}$	$\frac{1}{2\frac{1}{3}}$
Supported at the extremities	$\frac{1}{2}$	$\frac{1}{7}$	$\frac{1}{2}$	$\frac{1}{7}$	$\frac{1}{2}$	$\frac{1}{6}$
Supported at the middle	$\frac{1}{2}$	$\frac{1}{10}$	$\frac{1}{2}$	$\frac{1}{10}$	$\frac{2}{3}$	$\frac{1}{12}$

The values of bending and shearing strains here given are not put forward as strictly accurate, although, from the detailed calculations on which they rest, they may be regarded as very close approximations to the strains experienced by various classes of ships under the assumed conditions. These conditions, as we have seen, do not include all the circumstances in which ships may be and are placed, but for still water the approximation made is doubtless very close; and for the exceptional positions of support ashore, the limiting values of the strains are also very close to the truth, although in practice these limits can never be reached. For ships at sea, in the extreme positions of support assumed, the values given for the strains, of course, represent the statical aspect of the question; the attempt to put into figures the straining effects of pitching and ascending, has not been made.

THE EXPANSION OF WATER IN FREEZING.

From "The Engineer."

The effects produced by the expansion of water in freezing are of considerable importance to engineers, not only as affecting the permanence of water tubes, mains, etc., during winter, but as regards various other works, such as masonry, which suffer heavily under certain circumstances from the effect of frost. The following account of recent investigations in the matter will, we believe, be found interesting and useful. They have been carried out in a very careful and complete manner by MM. Ch. Martins and G. Chancel, Professor at the School of Medicine and Faculty of Science, Montpellier, and also separately by M. Boussingault and M. A. Barthélemy, whose names alone are sufficient guarantee for the value of the experiments made, and we propose to give our readers an abstract of the results of their inquiries. In the earliest experiments of the Florentine Academicians on the point, they determined first of all that water in freezing burst vessels of metal or glass which were completely filled, and, to measure the amount of dilatation which took place as the fluid passed into the solid state, they took two courses. In the first, by putting a certain quantity of water into a graduated tube, and then freezing it, they ascertained that the relative bulks of liquid and frozen water were between themselves as 8:9. In the second they primarily weighed a volume of water, and then found the weight of a second volume of the same equal in bulk to the ice resulting from the freezing of the first, these giving *inter se*, the proportion of 25 to 28¼, which appears not much at variance with the result of the earlier experiment.

In 1784 and 1785 Major Edward Williams burst in this way, at Quebec, some cast-iron bombs the exterior diameter of which was 12.8 in., and the thickness of metal about 38mm. During the operations the thermometer stood in the open air at about —24 C., and the fuse holes of the shells were stopped by an iron plug strapped over exteriorly with steel bands. In seven of the trials made the plug on the freezing taking place was forced out to a distance of about 125m., its ejection being immediately followed by the appearance of a small cylinder of ice varying in size in the different experiments from .057m. to .216m. On one occasion, at a temperature of—24 C. the shell burst, separating itself in halves, between which protruded two thin laminæ of ice of about the thickness of a fish scale, whilst the plug itself had partially yielded. Charles Hutton (see the "Transactions of the Royal Society of Edinburgh") deduced from the data furnished by these experiments the conclusion that whatever the intensity of the exterior cold, the resistance of the sides of the bombs to expansion maintained some portion of the inclosed water in a liquid state, and by calculating the volume of the largest exuded cylinder of ice he formed the opinion that the dilatation of water in freezing was from one-seventeenth to one-eighteenth of its bulk. Muncke repeated these experiments at Michelstadt, when he burst old shells 49 centimetres diameter, and a thickness of metal of 64mm., at a temperature of—20 deg. C., fragments weighing 75 kilos. being flung to a distance of ten paces, and his valuation of the rupturing force was that it equalled 132,000 kilos.

The experiments of which we write—those privately conducted by MM. Martins

and Chancel—were made on two large bombs, each of 0.32m. diameter, and 39m m. thickness of cast iron in the weakest part. After having been filled with water, closed with a wooden plug slightly conical driven in with a mallet, and covered by a heavy stone, the first of these was exposed in the open air on the night of the 3d of January, 1868. The plug was forced out, driving the covering stone on one side, and in the morning a small cylinder of ice made its appearance through the fuse orifice. This was removed, and the ice in the interior of the bomb having become partially melted from the effects of the sun's rays, water was added so as to fill it (the bomb) afresh, the plug being then replaced and weighted as before. During the following night the thermometer marked—6 deg. C., and the plug was again forced out by the issuing of a cone of ice. Another evening, the water having been replaced, the shell was again closed with a new plug of dry wood, driven in with very considerable force and weighted with a large stone; on that night the thermometer fell to—10.3 deg., and towards the morning a dull sound was heard, and the shell separated into two parts, in the line of a great circle, passing through the fuse orifice. The thickness of the skin of ice was found to average 60mm., which leaves 122mm. as the diameter of the sphere of water remaining in a liquid state.

The experiment was repeated on the 20th January, 1870, when the fuse-hole of a shell of the same diameter as the previous one was tapped, the bomb then filled with water at a temperature of about + 4 deg. C., and the orifice closed by a screw, the head of which was formed of a disc of iron corresponding exactly with the curve of the outer periphery of the shell, a washer of lead being placed between. The bomb was then immersed in a mixture of, by weight, two parts of snow and one of sea salt, the thermometer standing therein at—20 deg. C. In 6 hours the shell burst, but not in the line of its greatest diameter, a spherical piece from the side opposite to the fuse-hole, having a diameter of 0.19m. at its base, separating itself from the rest of the globe, and the mamelated layer of ice, circumscribing an irregular ellipsoidal cavity, was found to be from 2 to 3 centimetres in thickness. In another experiment a bomb, the metal being about 26mm. thick, and the interior capacity 2,610 cubic centimetres, filled with water at + 4 deg. C., plugged as the foregoing, was placed in a mixture of snow and ice of the temperature of—21 deg. C. At the end of an hour and a half the shell burst, dividing itself nearly on the line of a great circle into two slightly unequal parts. It was found that the interior layer of ice had an uniform thickness of 10 mm., and the diameter of the enclosed sphere was, therefore, 150mm., and the volume of the globe of liquid water 1796 c.c., that of the ice being 814 cubic centimetres, and, according to General Morin's formulæ, the pressure on the line of rupture equalled, say 290-, 000 kilos. From the fact of the extreme uniformity of the layer of ice which covered the interior of this shell, it was somewhat easy to calculate directly the force causing the rupture. The entire interior capacity of the bomb filled with water was, as we have said, 2610 cubic centimetres; after the explosion, this sphere was composed of 1,796 cubic centimetres of liquid water, with a surrounding layer of ice of a volume equalling 814 cubic centimetres; but as in freezing, water expands, the 814 cubic centimetres of ice had, in becoming solid, increased in bulk by one-eleventh, or about 74 cubic centimetres. The interior mass was, therefore, under a pressure equivalent to this increase of volume, which, in free space, would have raised the total quantities of water and ice united to about 2,684 cubic centimetres; but the interior of the shell having only a capacity equal to 2,610 cubic centimetres, the liquid sphere of 1,796 cubic centimetres was hence compressed to the extent of, say one-twenty-fourth of its volume; and the pressure which burst the shell is determined as being equal to about 912 atmospheres. It has been assumed in this calculation that the water alone is compressible. The ice is probably, however, very slightly so, the coefficient of its yielding not being known. But if we suppose this compact ice, deprived of air, to be equally compressible with water, we find the force causing the rupture of the shell along the line of a great circle passing through the fuze hole is reduced to 550 atmospheres. It may be assumed, then, that the rupturing force is within 550 atmospheres, if we admit the ice to be compressible like water, and 912 atmospheres, if we suppose it is not so. In an experiment made with a small grenade —whose interior diameter was 61.87mm., and its exterior one 81.49mm., with a thick-

ness of metal of 9.81mm.—it was filled with water and plugged, but, on being placed in the freezing mixture, burst in a quarter of an hour, the weight of the lining of ice being found to be 32 grammes, its average thickness 2.9mm., the volume of liquid water 92 cubic centimetres, and the rupturing force 440 atmospheres. Another grenade of one cubic centimetre superior capacity was operated upon in a similar manner, and the pressure causing the explosion determined to be equal to about 574 atmospheres, the difference between the respective rupturing forces in this and the former experiment being attributable to the varying qualities of the cast iron, its want of homogeneity, and the flaws which it nearly always contains. It remained, in order fully to complete these experiments, to see what was the temperature of the water remaining liquid in the centre of the shells. It is known that pressure lowers the freezing point of water, at the rate of about 1 deg. C. to every 133 atmospheres, and as to this, reference may be made to the "Transactions of the Royal Society, 1849," the "Proceedings of the Royal Society, 1861," the "Proceedings of the Royal Society, Edinburgh, 1850," "Bibliotheque Universelle, Archives Nouvelle, période 1858," etc. etc.; but the determining of this actual temperature offered no little difficulty, inasmuch as it was necessary, in order so to do, to place a thermometer in the centre of the shell to be burst, and yet protect it from the enormous pressure effecting the rupture; the means adopted were the following:—

Instead of using a simple screwed plug to close the fuse hole, as in the experiments already narrated, a hollow one was made which terminated in a tube of steel twisted like a gun barrel, and equal in length to the interior diameter of the shell; a thermometer, the bulb of which, surrounded with mercury, was exactly in the centre of the shell, was placed within this tube, the graduated scale passing through and being visible above the nut head of the screw plug, whilst its markings were read, by means of telescopes, from some distance. The shell was filled with water at + 4 deg. C., but prior to its being placed in the freezing mixture this temperature rose to 10.7 deg. When surrounded by the ice and water, this fell to + 0.1 deg. C., and twenty minutes after it was − 2.2 deg. Under the influence of the formation of the ice it then rose rapidly to − 0.7 deg., slowly afterwards descending to − 2.8 deg., when the shell burst, having been in the freezing mixture, the temperature of which was always below − 19 deg., two hours and thirty-five minutes. In calculating the pressure by the augmentation of the contained volume, it was found to amount to about $\frac{1}{4\cdot5}$, and, consequently, equal to the force of about 433 atmospheres, whilst from the knowledge obtained of the temperature of the water the following was deduced: The temperature in the centre appears to have been, when the explosion took place — 2.8 deg., and admitting, as do many natural philosophers, that the freezing point is lowered 1 deg. C., for every 133 atmospheres of pressure, it was found, by calculating the pressure from the registered temperature, that it was about 373 atmospheres, a result which differed but 16 per cent. from the other, and which was certainly an accordance to be considered satisfactory when experimenting with matter where all the physical elements of calculation cannot be quite accurately determined. Another bomb was afterwards tried, which exploded after having been in the freezing mixture one hour and thirty-five minutes, the thermometer standing at — 4.2 deg., and the pressure at the moment of rupture was calculated to equal, say, 559 atmospheres, the pressure corresponding to the increase in volume being 588 atmospheres. The conclusions arrived at from these experiments are, speaking generally, the following:

(1) The rupture of hollow vessels of cast iron by the freezing of contained water takes place without any projection of the fragments, the proportion of water converted into ice being from 20 to 30 per cent. of the whole.

(2) This quantity of ice creates an interior pressure which reduces the volume of the water by from $\frac{1}{4\cdot5}$ to $\frac{1}{3\cdot5}$.

(3) That the pressure required to burst bombs is independent of the size of the shells; the thickness of the metal in those used in the experiments under notice being proportionate to their volume, the resistance was about equal, and averaged 520 atmospheres.

(4) That the pressures deduced from the temperature of the water, allowing for a lowering of 1 deg. C. per 133 atmospheres, give results nearly agreeing with those calculated from the coefficient of the compressibility of the water.

(5) That in these experiments, no matter what the cold of the exterior freezing mixture, the temperature of the enclosed water was never at the moment of rupture below—4.2 deg. C.

(6) That the average pressure at rupture was only about half that given in the formulæ of General Morin.

M. Boussingault's experiments are also extremely interesting. He used a cannon, tapped at the muzzle, and closed with a screw pin of tough steel, having a washer of lead; a ball of steel being placed in the interior of the gun in order that it might be ascertained by it, the ball, becoming immovable, whether or not the water was frozen. On the 26th December, 1870, the cannon was filled with distilled water at a temperature of + 4 deg. C., and when the plug had been screwed in by the aid of a lever, on turning the gun the metallic sound caused by the movement of the enclosed ball was very distinctly heard. Exposed from 9 A M., when the temperature was —13 deg. C., until the evening, when it was —9 deg. C., the water inclosed still remained fluid.

On the 27th of the same month the thermometer marked—24 deg., and the continued movability of the ball proved that the water was still liquid. On the 30th, on proceeding to remove the plug, the temperature being—10 deg. C., the screw was scarcely turned when a species of frosty matter somewhat resembling the rime of hoar frost forced itself out, and the inclosed water, so soon as the pressure to which it had been subjected was removed, became frozen. The cannon was then warmed sufficiently to destroy adhesion, and a cylinder of ice of great transparency, with a row of small air bubbles along its axis, was removed. Other experiments conducted by M. Boussingault gave almost similar results, the water remaining fluid under pressure at very low temperatures, but freezing the moment when the removal of the plug gave it room to expand; and the conclusion he comes to is, that if the resistance of the sides of the inclosing vessel exceeds the expansive force developed during the act of congelation, this resistance becomes an obstacle to the formation of ice, and the water remains liquid at the lowest temperature—an opinion in the *rationale* of which we fully concur.

Those of our readers feeling interested in the further investigation of this question are referred to Professor James Thomson's discovery of the lowering of the freezing point by pressure, and to Messrs Forbes and Tyndall's observations of facts connected with glaciers.

BLAST FURNACE CONSTRUCTION.

From "Journal of Iron and Steel Institute."

The blast furnaces employed in smelting iron ores in Great Britain, beyond having been, from time to time, enlarged in size or internal capacity, remained without any great alteration in their external shape, or other improvement in construction, from the last century up to about the middle of the present one, being, during that period, little more than great pyramids of massive masonry surrounding a central cavity in which the smelting of the iron ores took place; many examples of these are still to be seen in various parts of Scotland, Wales, and Staffordshire. The commencement of the iron manufacture in the Cleveland district, however, inaugurated quite a revolution in this respect, as well as in many other time-honored details of our blast furnace practice; and furnaces were built which were but thin stacks or mere shells of brickwork, encased in an outer coating of plate iron, and under which the massive columns, or rather solid blocks, of brickwork or masonry, which formerly supported the body of the furnace, were replaced by cast-iron columns, which modification not only immensely reduced the quantity of materials required for the construction of the furnace itself, but also allowed of easy access to the region of the tuyeres and hearth of the furnace. On the Continent, however, the ironmasters were long in following the example shown by Cleveland; and to this day most of the iron furnaces are seen to be but copies of what the usual style of construction in England was before 1850. In 1865, however, it would appear that the first step in this direction was taken by M. Buttgenbach, the manager of the Neuss Iron Works, near Dusseldorf, in Rhenish

Prussia, who introduced his new system of blast furnace construction, which, although evidently based on that of the modern English furnace, differs from it in several details.

A model of his first furnace was placed in the Paris Exhibition of 1867, where it received the only prize in its class, and is now in the Museum of the Ecole Centrale des Arts et Manufactures in that city. Since then, blast furnaces on this system have been erected at the Usines d'Anzin, near Valenciennes, at MM. de la Rochette's, and at MM. Harel & Cie.'s ironworks, near Lyons; at the St. Louis Works, near Marseilles; and in Austria, at Inneberg, near Vienna, and at Putten, whilst various others are now in course of construction in both France and Germany. Descriptions and figures of the furnace will be found in the "Portfueille Economique" for October, 1869; the "Berg u. Huetten Zeitung" for 1870, p. 436; and still more recently, in Professor A. Kerpely's report, just published; and as this system is coming every day more into use on the Continent, as well as from its containing several features which may be found applicable to our own furnaces in Eng and, we think it may not be out of place to direct attention to the mode of construction as now carried out.

The principle on which Herr Buttgenbach's system of construction is based, is that the shaft of the furnace itself shall be as far as possible isolated and independent, either of the base below or the charging bridge above, in order that it may thus be enabled to expand and contract freely, without affecting the other parts of the structure. In order to effect this, the base of the furnace is formed of seven brickwork piers, disposed in a circle and inclining slightly inwards, their tops being connected by arches and by a crown ring, which rests in a recess formed in the inner side of the ring of brickwork on the top of the piers. The shaft which rests on this crown ring is built of one ring of fire-clay blocks, moulded to the proper form, and only 18 in. in thickness. The boshes meet the stack as usual, and at their widest part are held in by the crown ring of the piers, both the stack and boshes being braced with iron hoops, and at their junction the boshes are protected by water boxes, which are likewise applied to the hearth and to the tuyeres and tymp arch. The top platform, bridge or charging gallery, as it is variously called, is not supported by and has no connection with the furnace shaft, but rests upon five hollow wrought iron columns, which spring from the top of the base, these columns serving as pipes for carrying down the gases from the furnace top into an annular reservoir, in which all the dust collects, and from which they are conducted to the boilers, air-heating stoves, etc. At first glance it would appear that such thin walls would be likely to give rise to a considerable loss of heat from the cooling action of the surrounding air, but the experience of seven years with two furnaces at the Neuss Iron Works, the one built on the old system of thick walls, and the other with walls only 18 in. thick, formed of only one ring of fire-brick, without any other surroundings, have afforded practical proof that the new system is the more economical in working as regards the consumption of fuel; whilst these walls have the advantage of being more durable, since repairs can be made at any time during the working without the least difficulty, and any part of the wall may be examined by boring a hole of say 1 in. diameter through the fire-brick, which affords the means of ascertaining, at any time or in any part of the shaft, as to how far it may be worn away on its inside; this small hole being kept closed by a clay plug, put in from the outside. Owing to the cooling action of the external air, the shaft, which, as before stated, is only 18 in thick, during the seven years which it has been in use at the Neuss Works has not lost more than half-an-inch in thickness internally; it is braced every 3 ft. with iron hoops, 3 in. wide and $\frac{1}{2}$ in. thick, and has never shown any trace of gas escaping through its joints, whilst no damage or difficulty in re-commencing work was found when, in the commencement of this year, the furnace had to cease working during 62 days, on account of insufficient supply of coals. This furnace, which is 53 ft. in height and 16 ft. across the boshes, turns out nearly 50 tons fine-grained pig iron, rich in manganese, per day, with a consumption of from 20 to 22 cwt. of coke per ton of pig iron, and in cost of erection can be built for at least 25 per cent. cheaper than one of the same dimensions, but of the ordinary construction.

There is no cast iron used in the whole furnace, and the total weight of the hoops and braces does not amount to

two tons. If the blocks of the shaft are to hand, such a furnace can be built within a month, and as no mortar is employed, the joints of the fire-bricks being only cemented by a thin mixture of clay and water, the entire drying and heating previous to blowing-in does not require longer than ten days.

ON THE COMBUSTION OF POWDERED FUEL IN REVOLVING FURNACES AND ITS APPLICATION TO HEATING AND PUDDLING PURPOSES.*

From the "Mining Journal."

From the earliest period it has been the desire of all parties interested in the use of coal to produce perfect combustion and no smoke. Various mechanical means for bringing together, in a regular manner, the proper equivalents of air and coal, and for keeping clean the bars of furnaces, have been suggested, but none have hitherto succeeded, particularly where large quantities of coal have been burnt in a small space. To effect this it is necessary at all times to have an equal thickness of coal retaining the same area of interstices in it, in conjunction with free access of air between the bars at a regular pressure, without which it is impossible to maintain an equal temperature or equal combustion. The many difficulties which presented themselves to all those who have formerly investigated this subject, convince the inventor that the only means of effecting this, was by powdering the coal and feeding it together with the air by mechanical means, without the use of fire bars, so as to be independent of natural draughts, which are always a source of irregularity. It is not only necessary to have the means of bringing together the proper equivalent of air and coal to insure perfect combustion, but it is essential that the size of the particles of coal be determined, and should, during its flotation through the furnace, be so conducted that any undercharged or surcharged currents of air and coal should be continually re-intermixed until the whole of the carbon be consumed; otherwise, were this not attended to, there would be deposits of coal on one side of the furnace, and the free oxygen would pass on the other. The coal is ground and conveyed by the ordinary flour mill apparatus at a cost of about 1s. per ton, and fed from the hopper through adjustable rollers into an air injector, and introduced into the furnace mixed with air, which, during the experiments with fixed combustion chambers, was so directed on to the bottom that the undercharged and surcharged currents re-intermixed the products passing over the bridge into the utilizing chamber. The feeding apparatus was a great difficulty, the requirements of such a machine being regular action whether the coal be wet or dry. It was ascertained that from the intense heat produced, and other causes, there was rapid wear and tear of the brickwork, but observed that where a natural slag was formed the bricks were protected. The object then was to endeavor to consume so much as possible in contact with such slag, conducting the unconsumed products over the material to be treated without striking the brickwork. Under these conditions the combustion was so perfect that cold scrap iron was welded with 5 to 6 cwt. of coal per ton of iron, and this with cold air and without utilizing the heat in the chimney. It was mentioned by the inventor that he was not aware of any system, by which iron had been welded with so small a quantity of coal. The reason is obvious. The temperature is maintained by the perfect combustion of the air and coal without variation. In other cases, steel of the ordinary kind was melted in 1¾ hours, and in other instances 60 lbs. of *pure* wrought iron was melted in 3½ hours, a sample of which was shown. "This," he believed, "had never previously been accomplished by cold air and coal. It is an evidence of the extraordinary perfection of the combustion, since the theoretical heat producible is only in small excess of the melting point of wrought iron, and, had any variation in the quantities of air and coal occurred, such a result would have been impossible." Other experiments were made with a large marine boiler by taking out the fire-bars and lining the furnace with brick-work. The boiler contained 1,500 sq. ft. of heating surface.

* Abstract of a Paper read before the Iron and Steel Institute by T. R. Crampton.

In a 24 hours' trial the variation of temperature in the smoke box did not vary 20 deg. Fahr., that is between 380 and 400 deg. There was found no difficulty in evaporating 10 to 11 lbs. of water per lb. of coal. It is practically impossible to make smoke, as the whole of the hydrogen is consumed in the first instance. The consequence is that the uptake in boilers have no flame in them—an important element when superheating steam. By the use of this system in steamships no stoking would be required, and the coal consumed per hour would be a constant quantity whatever the length of the voyage. He believed, owing to the regularity of the heat, as much steam could be produced for ¾ of the heating surface generally used. Upon further investigation of this subject, it was deemed of great importance to form a revolving combustion chamber, and on working it out (at the Royal Gun Factories, Woolwich Arsenal, under the superintendence of Colonel Campbell), a puddling chamber was attached, forming a rotating machine divided into two parts, a circular aperture connecting them, the combustion chamber being lined with brick and the puddling chamber with fettling. A balanced flue piece, having a double casing through which water flows to cool it, is at the exit end of the furnace. The furnace itself is also double-cased, through which water is made to circulate, having a cock with an inlet and outlet passage attached in a line with axis of the furnace, through one of which passages the water flows, and after circulating in the hollow space surrounding the furnace, making its exit through the outlet in the same cock. The coal and air is injected through an annular space surrounding the water inlet, and strikes diagonally all round the combustion chamber, the products being deflected into the coal at the opening into the utilizing chamber, and pass over the work to be done, and through the movable flue to the stack. The combustion chamber is protected from the action of the fuel by a self-formed bath of slag which is continually carried round as the furnace rotates. The furnace on the outside is perfectly cool, and owing to there being no undue expansion or contraction, the lining and the fettling is most efficiently preserved. The puddling chamber is first lined with 1½ in. of fire brick, and then 3 or 4 in. of fettling is melted upon it. Eight charges of 5 to 6 cwt. is puddled in one shift, the pig iron being melted in the furnace itself, but it has capacity for puddling 12 to 15 cwt. The furnace weighs about 20 tons in working order, and is revolved by two small cylinders of 5 in. diameter with 10 in. stroke. At any speed the furnace itself is noiseless. One man is required to grind the coal for one furnace, but three men would do the work for six or eight of the same. The quality of iron produced, as compared with that made from the same pig, is somewhat interesting.

From the ordinary furnaces the iron after being puddled, and reheated and rolled three times, bears a tensile strain of 22 tons per sq. in. In this furnace the puddled ball, when reheated and rolled *once*, broke, never under 23 tons, and often at 26 to 28 tons per square inch, and these latter, when hardened, 38 and 45 tons per square inch respectively were resisted before fracture. The high quality of iron is believed by the inventor to be obtainable at will, but he considers that the subject requires further investigation both chemically and mechanically.

THE PREVENTION OF FLOODS.

From "the Engineer."

There is no question but that the employment of steam on a large scale, as a substituted motive power for water, and the superseding of inland navigation by railways, have gradually paved the way for an almost complete neglect of the utilitarian resources of our rivers and streams. If the evil of regarding in this light the water power of a country were to end here, the worst that could be said would be that we were blind to those advantages which were placed gratuitously at our disposal, and committed an enormous waste in the adoption of artificial means when natural ones were at our command. But a neglect of the powers of nature does not end here. To render them subservient to the use and benefit of mankind, they must be brought into subjection. If left free and uncontrolled they exert their potent influence in

the wrong direction, and ravage and destroy where they ought to beautify and fertilize. The clearing of forests, so that the sun may shine and the wind blow over the land, the drainage of marshes, the embankment of rivers, and the cultivation of the soil, are the first duty of colonists, and the inevitable prelude to civilization. Were any proof required of the disastrous consequences of the *laissez aller* system, so far as rivers and streams are concerned, it is to be found in the terrible inundations which, during the latter part of the autumnal season, commit so serious an amount of injury to property and individuals, not only in our own country but also on the Continent generally. The subscriptions which have been raised in our metropolis for the relief of those who have suffered in foreign countries from the depredations of their rivers, afford a tolerably accurate clue to the severity of their misfortunes. We cannot help remarking here, that however praiseworthy charitable motives of any kind are, there is such an axiom as "looking at home first." Moreover, alleviation is no cure, and having regard solely to our own annual losses from the same cause, it is evident that the proper plan of dealing with the evil, which is certain and inevitable in its advent, is not by periodical eleemosynary assistance. At the best, a temporary mitigation of the effect is all that is accomplished. The real cause remains as active as ever, and, like every other destructive power, increases in magnitude and violence with each succeeding year in which it is permitted to commit its ravages with impunity. In our opening article for the present year we briefly touched upon this important subject, and we shall now consider a little more in detail the difficulties that have to be encountered and overcome in practically dealing with the question of floods in an engineering point of view.

In the investigation of this subject several opinions formed of the causes which mainly conduce to the occurrence of floods, will appear somewhat paradoxical; but a distinction must in some instances be made between works carried out for the improvement of the navigation of a river and those intended to prevent its periodical inundations. Navigable rivers, although, as a rule, more under control than unnavigable ones, nevertheless "flood" very extensively. When more water is brought down a river than its channel can contain, and when it accumulates faster than it is carried off, the river "floods." It must be borne in mind that the ultimate destination of all water brought into a river is the sea, save what is lost by absorption and evaporation. It may seem a little curious that the cultivation of land—an indispensable accompaniment of civilization—is asserted to increase the tendency of rivers to overflow their banks. It is stated that the more extensive the cultivation the less the evaporation, and the greater the surface and subsoil drainage. Not only does more water find its way into the rivers, but, what is of much greater consequence, it accumulates there with far greater rapidity than that with which it can be carried away, and the result is that directly a low-lying district is reached an inundation takes place. There is, no doubt, some truth in this supposition; but, even so, it acts as a comparatively feeble cause in promoting the whole extent of the evil. At any rate, the remedy must be sought elsewhere than in the suppression or diminution of the cultivation of land. Whatever may be the real effect produced by it on rivers, it must, as a cause, remain, and means must be taken to accommodate the rivers to it so as to nullify any injurious action it may produce. Paradoxical as it may seem, there can be no question but that the partial embankment of a river very materially assists in the production of floods. Were a river completely embanked from its source to its embouchment, at all, or at a very large number of the points where banks were necessary, the tendency to inundation would be considerably diminished. But while exceedingly useful and beneficial to the particular portion of country lying on each side of it, a river embankment is anything but serviceable to those parts situated either above or below it. For example, the volume of water coming down stream, which was formerly allowed to spread, is pent up in the contracted channel of the river. At the commencement of this artificial *vena contracta* a check must take place to the flow of the water, which, in the case of a large quantity, results in a backing up of that part of the river above it, and a possible overflow. Again, the water which passes through the embanked channel acquires a greater velocity than that which it had previously, and leaves the channel with a rush, which may also

cause it to overflow on banks placed at a lower level. It was formerly considered that one of the first steps towards the improvement of a river was to "take the elbows out of it." In other words, to cut through the bends and make the stream flow along the chord of the arc instead of along the arc itself. A navigable river should evidently, similarly to a railway, be as straight as circumstances will permit. But Mr. Ellet, who made an elaborate report some years ago on "The Mississippi and Ohio Rivers," and who is quoted by Mr. David Stevenson as an authority on such subjects, contends that this so called improvement is no improvement at all, so far as the prevention of floods is concerned. On the contrary, he maintains that straight cuts across the bends of rivers tend to produce inundations, inasmuch as they shorten the distance of the flow of the water, while at the same time they increase the slope and the velocity. A volume of water accumulates, therefore, more rapidly in the lower part of the river under these conditions than previous to their existence. When the rivers are of sufficient magnitude to allow of the formation of deltas they act as serious obstructions in the lower part of the stream, since they decrease the velocity of the current and retard the flow of the water to the sea.

Whatever means may be adopted for improving rivers subject to floods, they must not be of a partial or imperfect nature. Unless the evil be grappled with in its entirety, it may as well be left alone. Embankments are the great need, and the next is dredging. This latter remedy is an expensive one, and, moreover, one which does not appear to confer the same tangible benefits as the former. The value of an embankment, which prevents land from being flooded which was annually in that condition, is self-evident to the proprietor, but the result of dredging operations, although equally advantageous, is not so palpably manifest. With respect to leaving the elbows in a stream instead of cutting them off, we differ somewhat in opinion from Mr. Ellet, provided the principle be adopted of improving the river throughout its whole course. But if the improvements are confined to particular parts only of the channel, especially if the parts in the neighborhood of the bends are left unaltered, it will then be certainly more judicious to let the bends also remain in a similar state. It is worth remarking that it is not a necessary sequence, that because a new channel is made for a river it will continue to flow in it. Rivers are extremely capricious in their behavior in this respect. They will frequently endeavor to find their way again along the old bed, and if defeated in the attempt will cut out another channel for their waters, rather than avail themselves of that which has been artificially prepared for them. River improvements, if intended to be effectually carried out, should be commenced at or near the mouth, and continued progressively up stream. All additional flooding in consequence of the works or during their progress, would be thus prevented, as their immediate effect would be to assist the flow of the water towards its natural outlet. A careful examination of that part of the course of our rivers situated near the mouth, would point out that many of them are much too contracted to carry off the quantity of water which comes pouring down at certain seasons of the year. Besides the narrowness of the channels in these parts, the bottom frequently becomes silted up, so that the depth and the velocity of the current are considerably diminished. These portions of the course of some of our rivers would require very extensive dredging. The construction of weirs, especially those placed obliquely across the stream, have proved by experience to be of great advantage in the upper part of a river. They have been employed in the Severn and the Shannon, and have afforded most satisfactory results. Lately some important works have been undertaken with regard to the improvement of the Rhine, which presented some serious difficulties, insomuch as the floods were of both a sudden and violent character. Occasionally they rose in the short period of 24 hours to a height of nearly 40 ft. The principal works consisted of the formation of dams or weirs, at convenient points in the stream, and the taking out of the bends by straight cuts.

Although every tenant and proprietor of land must be aware of the urgent necessity that exists for preventing the annual inundations which cause so much damage in a variety of ways, yet it is hopeless to expect that they will voluntarily make any united movement in the matter. Without union not only would any remedy be imperfect, but the attempt, to a certain extent, would be unfair. It would be unjust for one person to pay the whole cost of a work which

would benefit his neighbor more than himself, the said neighbor declining to bear any portion of the expense, knowing very well that the result of the improvements must be advantageous to his property. The proper method of raising the necessary funds for carrying out what would be a great national work is to levy a tax on the riparian landowners of every river, and apportion the assessment according to the respective acreages liable to be flooded. The assessment should be made on the number of acres belonging to each proprietor, and not on the river frontage he might happen to possess, because in the latter case many owners would escape contributing to the general rate, as their land, although equally open to floods, might not be within several hundred yards of the river banks. But a very small expense would attend the ascertaining of the liability of each owner, as the limits of floods could be readily ascertained by the non-commissioned officers and men of the Royal Engineers when engaged in the field in correcting the Ordnance maps. The points marking the flood limits could be sketched in at once on the plans, and the area subsequently determined in the office in an equally easy manner. The data upon which to base the assessment having been obtained, commissioners might be appointed by Government to hear evidence, settle disputes, and adjust conflicting interests. On the supposition that in order effectually to prevent the occurrence of floods it would be necessary to embank the whole, or nearly the whole, channel of the river, it is obvious that there would be some proprietors whose lands might have a river frontage and yet not be subject to floods. Whether they should be called upon to pay as well as their neighbors, and, if so, in what proportion, would be a question to be settled by the arbitrators. There is not the slightest doubt but that this enterprise ought to be carried out. As a nation, it is a disgrace that we should year after year witness with complete apathy a destructive agency at work without raising a finger against it. We are not a whit better than the indolent Oriental fatalists, who, rather than make the least attempt to divert a stream, allow it to sweep away entire villages, and cloak their laziness and cowardice under the flimsy disguise of submission to the will of Providence.

QUALITY AND STRENGTH OF TIMBER.

"From the Building News."

Numberless experiments have been made to ascertain the strength of timber. Hodgkinson, Barlow, Hatfield, etc., and more lately, Captain Fowke, R. E., have all paid attention to the subject, and written more or less voluminously on the matter, and it requires long and patient study of the different conditions under which their experiments were made, to arrive at anything like correct conclusions. Timber is so much affected by external or internal conditions, that it is difficult to find two pieces giving the same result, but all experiments have been made on wood which to all appearance was good and sound—a difficult matter always to ascertain. For instance, a plank wholly or in part formed from sapwood would break under strain much sooner than one taken from the heart, because the sapwood is imperfectly formed timber, which requires time to develop. Then again, the heartwood is the best only when the tree is young. At maturity, the timber is equally good in every place, and when in age, the heartwood is the first to decay, so that in the latter case, the wood just inside the bark, where sapwood is found in its youth, is the best part of the tree. Of late years, the cargoes from European timber ports have contained so much sapwood that it was evident there had been reckless felling. Carriage to the sea had become so very expensive in some places, that the question seems to have been how to get a shipload as near as possible to the port, and young trees have been felled which ought to have been left standing for many years longer. The American wood has been comparatively free from sap, the vast extent of her gigantic forests giving greater facilities for the wood to mature. Mr. John Anderson, C. E., a very good authority, says: "The strength of many woods is nearly doubled by the process of seasoning; hence it is very thoughtless to use timber in a green state, as it is not only weak, but is exposed to continual change of bulk, form, and stability. After timber is cut, and be-

fore it is properly seasoned, the outside is found to crack and to split more than the inside of the mass, because it is more exposed to the desiccating effect of the surrounding atmosphere; but as the outside dries, the air gradually finds its way to the interior. If timber is cut up by the saw when green, and allowed to season or dry in a gradual manner, it is found to be the most durable. Unfortunately, however, it is to be feared that most of the green wood imported into England is used, so far as the cheaper kinds are concerned, almost at once, or at any rate before it is properly seasoned. Such wood is bought for its cheapness, and to keep it a long time would be materially to add to its cost, and if people will insist on taking the lowest tender for their work—and we all know what a monstrous difference there often is between the highest and the lowest—they must expect to have warped joists and shrunken flooring in their houses. In the arts, artificial drying is often resorted to, as in the case of gun stocks. These are put into a desiccating chamber, where a current of air at 90 or 100 deg. is passed over them at such a rate as to change the whole volume of air every three minutes, and it is found that a year of seasoning may thus be saved. The walnut wood is as good after this process as if the seasoning had been accomplished by time and exposure, and works more smoothly under the cutting instrument of the stock machinery. It cannot be too widely known that a plank cut from the sap or imperfect wood for years will shrink in the breadth, and if cut from heart-wood, it will shrink in thickness, keeping the full dimension in the middle and tapering to the edges. By observing from which part of a tree the wood has been cut, which may be ascertained by examining the end, the future behavior of a deal may be safely predicted, and the evils of shrinking in a great measure prevented; for, although there is a modification of this law in the case of spruce, yellow pine, and other soft woods, such as are used for building purposes, still for all practical purposes the same rule applies.

The ultimate cohesion or tensile strength of the ordinary descriptions of timber in use is given by Barlow, Bevan, and Muschenbroek as follows, the ultimate tenacity being given in pounds per sq. in. of section:

Ash	from	19,600	to	15,784
Beech	"	22,200	"	11,500
Elm	from	14,400	to	13,489
Fir	"	18,100	"	7,000
Do. American		12,0 0		
Do. Memel		11,000		
Do Riga		12,600		
Oak	from	19,800	to	9,000
Do. English		15,000		
Do. African		14,400		
Do. Canadian		12,000		
Do Dantzig		14,500		
Teak	from	15,000	to	8,200

Mr. Anderson gives a most useful table. He takes the experiments of Tredgold, Barlow, Ebbels, and others as a basis, and shows what the calculated breaking weight in pounds of a beam 1 ft. long and 1 in. square is, of the following descriptions of wood: Ash, 595 to 810 lbs.; beech, 518 to 704 lbs.; elm, 337 to 540 lbs.; American fir, 483 to 570 lbs.; Christiania fir, 489 to 686 lbs.; Memel fir, 545 to 577 lbs.; Riga fir, 282 to 530 lbs; Canadian oak, 572 to 589 lbs.; Dantzig oak, 392 to 659 lbs.; English oak, 420 to 964 lbs.; and Teak 642 to 1,075 lbs. These beams are supposed to be supported at each end, and loaded in the centre. There is much difference in all such tables, arising partly from the different nature of wood, even when brought over in the same ship, and also from the different manner in which experiments are carried out; but as they stand, they are very useful to all interested in the building trade.

Good Riga, Memel, or Dantzig timber has always been preferred for beams, and when the piles employed at the Thames Embankment were drawn and put up to auction, there was some brisk competition amongst builders for them, as they had been well selected, and were little the worse for being used. They were Dantzig, for the most part, and some of these very piles were worked up, a week or two afterwards, into some large houses on the Westminster estate, and no doubt will last all the longer for their being immersed for such a time in water. Red pine used to be employed very largely for beams, etc., but hardly any comes to this market now, and Swedish timber, which resembles it, is hardly safe for heavy weights.

Although iron is extensively used for purposes where strength is of great importance, still the import of timber goes on increasing year by year, so that there is no fear but that all the information we can get respecting it is still needed. There are many curious laws affecting the stability of beams. For instance, their resistance to a sudden weight falling on them follows a very diffe-

rent law from that which regulates their strength. The experiments of the Railway Commissioners show that a beam 12 ft. long will only support half of the steady load that a beam 6 ft. long of the same square will support; but that it will bear double the weight suddenly applied; or, if the same weights are used, the longer beam will not break by the weight falling upon it, unless it falls through twice the distance required to fracture the shorter beam. This supposes that the timber is of precisely the same nature, for it is by the longer beam bending that it supports the fallen weight without fracture. To conclude, the relative strength of a girder or beam, so far as it depends on the manner in which it is loaded and supported, is very simply expressed by Mr. Anderson, C. E. Taking a girder of a given span, the load may vary in the ratio of 1 to 8, according to the different ways in which the girder is supported and the load distributed.

Position of support and load.	Relative Strength.
When supported at one end and loaded at the othor	1
When supported at one end, and load distributed	2
When supported at both ends, and loaded at centre	4
And when supported at both ends and load distributed	8

COAL IN CHINA.

From "Iron."

As, in the opinion of some philosophers, the coal-fields of England are destined to prompt extinction, it is not uninteresting to inquire what will become of Britannia at the end of—according to the widely different estimates of various *cognoscenti*—100, 300, or 1000 years. If, as we have been told *usque ad nauseam*, the mercantile supremacy of England depends less upon the active energy and dogged obstinacy of her children, than upon the accidental possession of vast fields of coal, the exhaustion of our coal-pits threatens to humble the "Lords of human-kind," and to reduce their pride of port to absolute zero.

From a cosmopolitan, rather than from an English point of view, the outlook is by no means disheartening. During the year 1872, the United States of America produced 41,491,135 tons of coal, or about one-third of the total product of the United Kingdom. These figures show an increase of 3,000,000 tons over the output of 1871. About one-half of the total was composed of anthracite, or "hard coal," the remainder being bituminous, or "soft coal." There is little room for doubt that the coal supply of the United States could be greatly increased, were it not that the disproportionate price of labor acts as a check upon production.

But the coal-fields of Pennsylvania—vast as they are—shrink into insignificance when compared with those of China. The coal-fields of the Celestial Empire cover an area of 400,000 square miles: about 33 times the extent of those British stores which have sufficed to make this country the workshop of the world. In the great province of Hunan, a coal-field extends over an area of 21,700 square miles. Hunan boasts of two distinct coal beds, one bearing bituminous coal, and the other anthracite—the latter being favorably situated for water transit, covering an area equal to that of the anthracite coal-fields of Pennsylvania, and yielding anthracite of the best quality. The province of Shansi possesses the enormous coal-area of 30,000 square miles. This is capable of supplying the whole world for thousands of years, even at the present rapid rate of consumption. The beds vary from 12 to 30 ft. in thickness, while the system of coal-bearing strata in Shansi is about 500 ft. in thickness, and has every facility for mining. An immense supply of iron ore adds to the mineral wealth of this great province. According to Baron Richthofen, only one kind of iron ore is used by the Chinese: "a mixture of clay iron ore and spathic ore, together with limonite and hematite" which occurs in "irregular accumulations in certain limestone strata at the bottom of the coal formation." All kinds of material lie ready at hand. "The few hundred feet of coal-formation furnish: first, an iron ore of great purity, rich in metal, and easily fusible; second, all sorts of clay and sand, such as are required for crucibles, moulds, etc.; third, a very superior anthracite."

It may appear strange that—possessing all these advantages, and lying amid a

population of 200,000,000 of the most industrious, most orderly, and most acquisitive people in the world—the coal-fields of China have yet been turned to little account. A little trade is carried on in the province of Szechuen, in the northern province of Chih-li, and in Manchuria. In Hunan sufficient coal is produced to feed such distant markets as may be reached by river or canal boats, but, in point of fact, China—possessing more coal than any country in the world—is actually a large importer of both coal and iron. The reasons for this curious state of things are twofold. Firstly, the mode of working is at once tremendously severe and ludicrously ineffectual: the shafts are not perpendicular, but are inclined planes, four or five hundred ft. in length, running down a slant of about 45 deg. Mr. Adkins, British Consul at Newchang, Gulf of Pechili, describes the men as carrying the coal up this slant in baskets, one being attached to each end of a short carrying-pole, which is borne upon the left shoulder. The shafts are nearly 7 ft. high, and about the same breadth, with a wooden roof, beams on both sides for support, and wood along the floor, so arranged as to form steps up which the miner with his load pulls himself by catching the projection of a step above him with a small curved staff, which he carries in his right hand. This barbarous method proves expensive, even in a country where labor is cheap; but the primitive nature of the mining operations is a small drawback when compared with the second great difficulty—that of conveyance. The coal districts reported upon by Mr. Adkins are only 100 miles in the interior of the country. By the time the coal reaches Newchang it fetches from 31s. 6d. to 49s. 6d. per ton. The quality is excellent, but the price is tremendous, and the difficulties attending the transit from the mines to Ying-tze, the port of Newchang, are so great as to deprive the place of all chance of becoming a coaling station for steamers—a great desideratum in northern Chinese waters.

Tartar dynasty, competitive examination, and the iron rule of a bureaucracy, are small impediments in the way of Chinese progress, when compared with the almost entire absence of roads. The much talked of system of canals is confined to the lower basin of the Yangtsze. In this section of the country, the land is cut up into a series of insular blocks by canals, which supply a means of transport—slow, perhaps, but unsurpassed both for safety and for cheapness. But this network covers but a comparatively small part of China, and the primitive mode of navigation at the disposal of the natives, causes half the advantages of the natural waterway to be lost. Where steamboats have been introduced, the trade has quadrupled, as these vessels not only achieve an immense amount of work, but afford an almost perfect security from piracy—the bane of Chinese commerce.

Roads are simply in a state of nature. Mere lines of deep ruts mark the track of the primitive vehicles of the country. By the time that these ruts render the track impassable, the rain steps in and washes them level again, the sun hardens the slushy mass, and this natural process of repair is deemed sufficient for the wants of man.

These primitive roads are traversed by equally primitive vehicles. In some provinces an imperfect service is performed by the means of two-wheeled vehicles, but these indications of civilization give way in the central provinces to the one-wheeled carriage—the primeval wheelbarrow; and in the hilly districts, these rude machines are again forced to give way to beasts of burden. The Chinese wheelbarrow is a peculiar machine. Under favorable circumstances Eolus is pressed into the service; a sail is hoisted and the efforts of an entire Chinese family, aided by a favorable breeze, sometimes drive a wheelbarrow 30 miles a day. As land freight costs from twenty to forty times as much as carriage by water, it is not difficult to see why the cost of conveyance makes the working of coal and iron mines practically impossible. In the province of Shansi, coal which costs 1s. per ton at the mine, rises to 24s. at the distance of 30 miles, and to over 42s. at a distance of 60 miles, so that only those who live almost at the pit's mouth derive any benefit from the coal mines of the Celestial Empire. This difficulty, amounting almost to impossibility of transit, presses with equal weight upon every department of Chinese industry. The crops are splendid, but there are no means of reaching the market, and the apathy produced by the want of means of transit amply explains why famine is a chronic scourge in the land of plenty.

Of all the fields open to British enterprise, China is undoubtedly the richest. Untold mineral wealth lies dormant in the earth,

and only awaits the vivifying touch of King Rail. The introduction of a railway system into China would not only enrich the proprietors, but would confer immeasurable benefit on the inhabitants of the country. It has been proposed to tap the great province of Hunan by extending a railway from Upper Burmah to the confines of the Celestial Empire, and the project has this great advantage—that it would turn the trade of a vast section of China through a British province. Chinese exclusiveness to the contrary notwithstanding, there is little doubt that the shriek of the steam whistle will, within a few years, be heard within the confines of the Empire of the Sun and Moon.

Thus the whirligig of time brings about its revenges. The whilom empire of Timur is destined ere long to become a network of railways built of English iron and driven by English coal. May not the island, once parcelled out among his followers by a Norman Duke, draw, at some future time, its supplies of coal and iron from the land of Confucius?

RAILWAY GRADIENTS.

By H. HAUPT, C. E.

Written for Van Nostrand's Magazine.

The paper now published was written in 1870, as part of a report on the reconnaissance for the Shenandoah Valley Railroad; reference was made to it in the published portion of the report, and several requests made by members of the engineering profession for copies, which could not be conveniently complied with.

As the article is not precisely in proper shape for a scientific magazine, and as the author cannot spare the time required to rewrite it, this explanation may possibly be accepted as an apology for defects.

GRADIENTS.

Two important objects should be sought in the arrangement of the gradient on any important line of road, and these are economy in construction and in operation.

To understand the propriety of the proposed recommendations it is necessary to observe, that an ordinary run of a locomotive is about 100 miles per day, but it is preferable to make the working distances on a long line as nearly as possible 50 miles, so that each engine will travel this distance and return.

By this arrangement the repair shops will be located at intervals of about 100 miles. Each engine will receive its repairs at the same shop, so that accounts can be properly kept and responsibility fixed, and at the end of each run of 50 miles time is afforded for a thorough examination and adjustment preparatory to the return trip.

The load of an engine on any working division of 50 miles is determined by the maximum resistance offered by grade and curvature, and except where assistant engines are employed no greater load can be carried over the division than can be carried over the point of greatest resistance. While, therefore, it may be expedient to make large expenditures to reduce the maximum resistances on any division, yet when these have been established it is not proper to sacrifice capital by reducing points of less resistance, as not a single car could thereby be added to through trains, or any appreciable economy of operation secured.

The angle of friction is that on which a train would just move or continue in motion by gravity alone.

This angle has been practically determined by the actual load of engines on different gradients of the Pennsylvania Railroad, where the eastward trains are loaded to the capacity of the engine[1]; the angle of friction was thus found to be 24 ft. to the mile, and the gross load on a level 1,200 tons with the standard engine there used.

On a grade of 24 ft., therefore, the power required to move 1,200 tons would be doubled, or an engine would carry but 600 tons; on a grade of 30 ft. the load would be 541 tons; on 84 ft. 270 tons, or one-half the load on 30 ft.

This being understood, an attempt will be made to prove, contrary to the generally received opinion, that undulating gradients below the limits of maximum resistance are not objectionable, and that while admitting of great economy of construction they do not materially increase the cost of operation as

compared with uniform and low gradients between the same points, also that the use of higher gradients for part of a given distance will often result in greater economy of operation than a lower and uniform gradient for the whole distance.

It was formerly the practice of Engineers to compare different lines of railway by conceding a given amount of rise and fall as equivalent to a mile of distance. This is not correct practice; the profile of the line and the direction and amount of tonnage, or, in other words, the maximum resistances and their distribution over the line, are the elements to determine questions of relative economy of operation; the rise and fall affect the question very slightly.

If the maximum resistances can be concentrated at one point and overcome at once with the aid of assistant engines, while lighter gradients in favor of the direction of the tonnage prevail on all the rest of the route, the line will be operated cheaply, but if the maximum resistances are scattered over the whole line at intervals more or less remote, the operation will be expensive.

In the solution of problems in railway economics it is not safe to apply general rules or principles too freely.

Each line presents a problem in itself the solution of which should depend on the particular data which the case presents; millions of dollars have been sacrificed by conforming to general rules and theories when circumstances required variations.

As a case in illustration, 30 miles of a railroad in Massachusetts were located on a uniform gradient below the maximum resistance of the division, and if constructed on that line the cost would have exceeded a million and a half of dollars. A million doll rs were saved by a change of location and of gradients which did not reduce the load of an engine over the division a single pound, the gradients used being still much below the limits of maximum resistance of the other portions of the division.

One or two practical illustrations will be given, having reference to the system of gradients recommended which will make this subject sufficiently clear to the practical reader. Suppose the gradient which determines the load of an engine over any division is one of 36 ft.. to the mile, and that it would be practicable by an expenditure not excessive to locate a portion of the division with a uniform ascending gradient of 6 ft. to the mile, but that by ascending at the rate of 36 ft. to the mile for five miles and descending 24 ft. to the mile for the remaining distance a large saving could be effected in construction. There are few perhaps who would not make a sacrifice to secure the lower gradient, and yet it can be shown that it has no advantages even in economy of operation over the undulating and much higher gradient.

A 6 ft. gradient requires one and a quarter the power required on a level, and in 10 miles the power may be expressed by $1\frac{1}{4} \times 10 = 12\frac{1}{2}$. On a 36 ft. gradient the power required is $2\frac{1}{2}$ times that on a level, and for 5 miles would be represented by $2\frac{1}{2} \times 5 = 12\frac{1}{2}$, but in descending the next 5 miles at the rate of 24 ft. to the mile no power will be required, as gravity will move the train; therefore the whole expenditure of power in passing over the 10 miles will be the same in the second case as in the first.

Again, assume as before that the ruling gradient which determines the load of an engine is 30 ft. to the mile and that an elevation of 1,090 ft. in 23 miles may be overcome either by using a uniform gradient of $47\frac{1}{2}$ ft. for the whole distance, or a 30 ft. gradient for 15 miles, and an 80 ft. gradient for 8 miles.

At the same cost of construction a majority of engineers would adopt the uniform and lower gradient, but it can be readily shown that the higher gradient for part of the distance will be much more economical. As the engine is supposed to be fully loaded for a 30 ft. gradient, any increase above this limit involves the use of additional power, or what is generally done, the splitting up and reconstructing of trains. If assistant power is used, economy requires that the power should be worked to its capacity; there would be great waste in sending an engine only half loaded. Now, the gradient which doubles the power required on 30 ft. is 84 ft, and it requires no argument to prove that it would be cheaper to use the double power on 8 miles rather than on 23, and therefore to extend the 30 ft. gradient for 15 miles and use 84 ft. for the remaining 8 miles is far better than $47\frac{1}{2}$ ft. for the whole distance of 23 miles.

These figures and this illustration have been used because they apply exactly to a case in point in overcoming the summit between New River and James River at the head of Potts' Creek, but there is yet another

and a very important consideration in favor of the adaptation of the higher gradient, which arises from the fact that streams near the summits almost invariably fall much more rapidly than the average for the whole distance, and along a valley bounded by mountains the uniform grade would throw the line high above the stream, encountering spurs and deep gorges and greatly increasing the cost of construction as compared with a line conforming more nearly to the fall of the stream.

Another consideration is that the higher gradient allows advantage to be taken of favorable ground; and to avoid difficulties, flats on the sides of mountains may often be reached and spurs avoided by variation of grade within the maximum limit where the uniform gradient would admit of no variation.

To those who have not given the subject particular attention the cost of operating a high gradient by assistant power when concentrated at a single point will be surprisingly low.

Taking the report of the Virginia and Tennessee Railroad as furnishing data nearest the locality of the Shenandoah Valley Extension, the cost of an engine per mile run, for fuel, oil, waste, repairs, engineer, fireman, etc., averages 35 cents. For a distance of eight miles it would be $2.80, and although the engine would return empty this allowance will be doubled for the round trip making it $5.60, which should be in excess of actual cost.

The gross load in 30 ft. gradients being 540 tons the net load would not be less than 240 tons, and the cost of assistant power per ton would therefore be 23 mills.

If one such gradient occurred in 100 miles the cost of assistant power would be less than a fourth of a mill per ton per mile, and if only once in 200 miles the cost would be less that one-eighth of a mill per ton per mile.

The cost per mile run of freight trains on the Virginia and Tennessee Railroad was last year, for transportation, machinery, and road expenses, 111 cents; as the whole cost of assistant power on a round trip of 16 miles was $5.60, it is obvious that the increased expense of overcoming the elevation assumed for illustration by an 84 ft. gradient would not be more than the expense of operating 5 additional miles of 30 ft. gradient or 2½ miles when the return trains are taken into account.

Simplicity rather than rigid accuracy has been sought in these illustrations.

The object has been to remove unreasonable prejudices against high gradients when properly employed, and to satisfy the Board of Directors that the system of high gradients recommended for the Shenandoah Valley Line, admits of an economy of operation that cannot be approached in any of the great leading lines of the country crossing elevated summits or in mountainous regions. The nearest approach is the Pennsylvania Railroad, and the credit of this is due to J. Edgar Thomson, by whom the gradients were arranged before the writer became connected with the road It is probable that upon the Shenandoah Valley Line, there will be five tons carried east, for one in the opposite direction; it is necessary to determine, therefore, the maximum gradient ascending westward, that will be equivalent to 30 ft. ascending with full trains eastward.

The gross load of an engine on a 30 ft. gradient was given at 541 tons, the net load 240; one-fifth of this would be 48 tons, which added to the dead weight of engine and cars would give the average gross weight of westward trains 380 tons, which would be the load on a grade of 53 ft. nearly. If assistant power should be used, the grade ascending westward equivalent to 84 ft. eastward would be about 150 ft. (see, for computation of effect of gradients in paper read before the American Philosophical Society and published in "Van Nostrand's Magazine").

If, then, it shold be found practicable without excessive expenditure to descend from the summits eastward with gradients not exceeding 53 ft., it should be done; but if the expense should be too heavy and higher gradients employed so as to require the use of assistant engines ascending westward, then gradients as high as 130 ft. in that direction might be employed to advantage so as to limit the use of such engines to the smallest number of miles.

My conclusion in regard to gradients is, that a line can be located between the point of intersection with the East Tennessee, Virginia and Georgia Railroad, near Russellville and Covington, on the Chesapeake and Ohio Railroad, with no ascending gradient eastward exceeding 30 ft. and no ascending gradient westward exceeding its equivalent for single engines in that direction of 53 ft., excepting at one and pos-

sibly at the two main summits dividing the waters east and west of New River, where the equivalent gradients for assistant engines of 84 ft. ascending east, and 130 ft. ascending west, should be employed.

These high gradients are recommended.

FUTURE NAVAL TACTICS.

From the "Nautical Magazine."

The discussion of military subjects has become a recognized function of the public press, both daily and periodical. It must be deeply wounding to "men of peace" to find how large a portion of the daily newspapers is devoted to the consideration of things purely military and warlike. Sometimes it is a leading article; sometimes a special, or "occasional" essay; sometimes a cluster of letters, dignified with the honors of *leaded* type; sometimes all and each of these. "Our own" no longer divides with "our special" correspondent the distinction of alone supplying information from foreign countries, and on matters of present interest to the thousands of readers, who have both time and inclination to carry their researches beyond the telegrams and the City Article, "our military correspondent" now claims his share in the distinction. It is not, perhaps, too much to say, that during the Parliamentary, and what, in view of past and coming events, we may be justified in calling the "Tichborne" recesses, few portions of the day's paper are more largely read, or more generally discussed, than the various essays and articles on military subjects which it contains. At one time we are treated to new views on organization; at another to suggestions for improving our system of tactics; at a third to a statement of the relative merits of "Armed Sense," and "Armed Science." When the advertisement columns are filled with announcements of the contents of forthcoming magazines, it would be difficult to scan them without lighting more than once on the titles of papers with a thoroughly military scope and object. Indeed, so marked a feature of periodical literature has this become, that in a late number of one of the "Service" journals, a writer jubilantly suggests that one magazine, not hitherto considered more specially warlike than its contemporaries, should insert in its title the word "military." It is, perhaps, only a symptom of an ineradicable tendency of human nature, that all this warlike literature treats almost exclusively of the methods and appliances of land warfare. Even in a nation, which, in spite of Mr. Reed, is much given to complacent assertions of its maritime pre-eminence, and of its intense interest in its Navy, many great questions which intimately concern the efficiency of the latter are allowed to remain unnoticed and undiscussed. Mankind still retains an unquestionable predilection for the older of the two forms of warfare. Whatever be the abstract reason for such a fact, we may leave to metaphysicians to discover; but, unless we fail to read many signs aright, a fact it is.

Naval affairs have been by no means altogether excluded from public notice and discussion. On the contrary, some have been discussed with a heat and acrimony that could be hardly surpassed in a theological disputation. There is indeed some danger that the discussion of some branches of the naval art has been carried from the scientific to the polemical stage of argument; and worsted disputants on questions of naval architecture have even gone so far as to "take the law" of their opponents. Nor have questions of ships' armament been argued with less fervor. Advocates of rival systems of ordnance, having grown tired of attempting to convince each other of the superiority of their own or their friends' inventions, have—after a long interchange of hard names and imputations of unfairness—at last gone the length of holding up their antagonists to popular derision with a somewhat gloomy humor in lampoons. But though the great British public is perhaps not always disinclined to witness a "set to," it is still apt to grow tired of the incessant rounds of an interminable fight; and it may not be amiss to try and direct its attention to some questions of naval warfare, which, if not in themselves interesting, are at all events of paramount importance. Not that the subjects to the discussion of which allusion has been made, are not also highly important; but they are by no means the only ones which a great naval nation should wish to see discussed and

illuminated by the light of recent inventions and the rapid progress of science. If we are to confine ourselves solely to a series of arguments about curves of stability, metacentric heights, thickness of plating, energy on impact, ribbed and studded projectiles, erosion of gases—useful and important as a correct knowledge of these matters undoubtedly is—and leave out of sight the consideration of how we are to use our armor-protected and steadily-carried weapons on the only occasions when they can ever be called into use, we shall somewhat resemble the "Greeks of the Lower Empire," indignantly cited by Napoleon, who were absorbed in grammatical disputations whilst the enemy was thundering at their gates. It may fairly be assumed that the chief object of possessing, or of trying to possess, that rather Utopian conception, the perfect ship-of-war, is to be able to make use of it, when it may unhappily be necessary to do so, with the best effect. In order to do this—it is perhaps almost a truism to state—our officers require some acquaintance with a definite system of naval tactics. That is just what we have not got, and what we do not seem much inclined to bestir ourselves to procure. Considerable attention has lately been—indeed is actually now being—devoted to devising a new system of tactics for our army. It is not improbable that that force which, in after-dinner speeches at least, is generally styled "our *first* line of defence," would, *ex vi termini*, be *first* required to test its own peculiar tactical system. Let us devoutly hope that ere that time arrives it may have something of the kind. What should we think of the efficiency of the British Army if its tactical system had undergone no real improvement since the days in which the "Swedish battle," as devised by the great Gustavus Adolphus, was the model on which were formed all systems of military tactics? Yet analogous to this state of things is the condition of the British Navy as far as its tactical efficiency is concerned. Nothing had more completely stagnated than did the art of naval tactics from, as the old sea song has it,—

> —— the days of the Rump and Admiral Trun.p,
> When Dutchmen wore bladder-legged breeches,

down to the time of Rodney's great victory over De Grasse in 1782. The first attempt to devise a tactical system for ships propelled by wind and sails, and armed with guns on the broadside, dates from the seventeenth century; such a system has in many essential particulars been continued even to our own time. It would surprise many to find, as they would find, on comparing whatever tactical instructions we now have, with those of the age just mentioned, how little we have improved on the older ones. But great as has been the revolution in the land warfare, caused by the improvements in arms and organization, that in sea warfare has been far greater. The sea service, equally with the sister service on land, possesses all the improved weapons, and, besides them, there has been placed at its disposal powerful ships constructed on entirely new principles, and propelled by a hitherto undiscovered motive power. Almost every condition of naval warfare has undergone a total and complete change since the date of the last great battle of the British Navy. It may be that our fleet is never to fight another, but as we still appear determined to have a fleet, there is something to be said in favor of adopting some plan which may render its power effective. How little near we are to such a consummation may be seen by anyone who cares to investigate the subject on reference to a lecture delivered by Captain P. H. Colomb, R.N., at the Royal United Service Institution, no longer ago than the early part of the year 1872. Captain Colomb has for some time been honorably known for his labors in connection with the evolutionary and signal systems of the Navy—systems, be it known, on which the art of naval tactics entirely depends. He has naturally been induced to extend his consideration to the tactical system demanded by present requirements, and no one will deny that he brings to such consideration all the merit of an expert. He has another merit, not perhaps so common amongst naval tacticians—viz., that of possessing a graceful and fluent literary style, and the faculty of presenting to his readers even the dry details of naval evolutions under an attractive and interesting aspect.

It is worth while to listen to what he says. "These remarks," this passage occurs in the lecture of which we have been speaking, "are not unnecessary at the outset of my paper. There is not one of us naval officers who has not either heard or expressed the most decided opinions on the efficiency of certain formations and the inefficiency of others. Yet I venture to say

not ten per cent. of us have ever heard any good reasons as to why one formation is better than another; and not two per cent. have ever thought out the matter even superficially for themselves. The danger we run of committing ourselves to some definitive theory of attack and defence without any inductive steps leading up to it, is real and tangible; and if, instead of advocating a particular view, it should come to pass that I show the end further off than ever, and leave your minds open on the questions, I shall not consider I have done bad service." Again, speaking of the non existence of any plan or system, he proceeds: "For if I be wrong in supposing a bad compulsory plan to be worse than no plan, still, as no plan is yet adopted, such investigations as mine go far to establish, not only a plan, but if properly conducted, a good plan." This is tolerably strong evidence, from a witness more than anyone likely to know, that whatever be the condition of the Navy as regards powerful ships and guns, its tactical efficiency is, to say the least of it, not perfectly satisfactory. Yet no one can more strongly express the opinion that it is quite possible to devise such a system of tactics as the present state of naval service has rendered necessary. "Much of the neglect," thus Captain Colomb begins his lecture, "under which my subject undoubtedly lies, may proceed from an idea which impressed me very strongly at one time, namely, that the attack or defence of a modern fleet cannot be profitably studied prior to the experience of many actual combats. It seems at first sight probable that no such thing as rule or law can be evolved except from the facts of experiment in war. It is, therefore, readily assumed that naval strategy is not yet in a condition to be made a subject of study. This line of thought would be excusable after many failures to discover the hidden law or laws which may exist, but it does not excuse the neglect to seek for them. We have no business to make the assumption in the first place, for it is founded on no data; and, moreover, I trust I have shown in former papers that so far from being the vague conglomerate of conflicting opinion generally supposed, a very superficial analysis recovers many points of absolute certainty, round which theories may safely revolve, or, at the very least, gives encouragement to persevere." But it is not necessary to rely solely upon the evidence of Captain Colomb, important though it be, to show that our tactical system has yet to be discovered. In the reported discussion which followed the delivery of the lecture will be found an unanimous agreement on the part of all who took part in it, that such is the case. The testimony of that most distinguished and veteran officer, Admiral of the Fleet Sir George Sartorius, need only be adduced in support of Captain Colomb's assertion. He said: "It is very necessary that some good theory should be now formed upon the management of fleets and ships, and future war tactics, based upon the best materials we actually possess, in order to prepare and be in readiness for cont ngencies before they arrive." It is an historical fact that the greatest impulse given to the improvement of naval tactics was due to those who were not seamen, for example, the Jesuit Father, Hoste, and the Scottish Laird, Clerk of Eldin. And in our own day Sir Howard Douglas began a work which, had he lived longer, he might have continued to the great advantage and improved efficiency of the Navy, which already owed him so much. It is therefore, perhaps. not by any means too wild an aspiration to hope that, in the absence of any practical experience of naval war, the art of tactics may receive new developments from the thought and study of those who in these days devote themselves to securing and improving the maritime power of the country.

Of the sea fights of the future, it may be almost asserted that we do not know how they will be begun, how they will be carried on, nor how they will end. The perpetual see-saw in the superiority of the gun and the armor-plate respectively, renders a prediction of the future value of either rather hazardous. But we may at least enumerate the various new weapons which science has placed at the disposal of naval officers, and the several methods in which these most destructive instruments are intended to be used. Ancient prescription and modern popular favor give in any such enumeration, the right of priority to the gun. The art, of which the rules govern the use of that weapon, is very modern. Naval gunnery dates in reality from a period more recent than the battle of Navarino, at which officers still on the active list of the Navy were present. The age of rifled ordnance is hardly yet in its teens; and even now the latest additions to our stock of guns have not yet been tried

afloat. Sinope, which shortly preceded the actual Crimean war, was the first important naval action in which shell fire from guns, as distinguished from that from mortars, played any great part. Our present weapons are in reality and in name, arms of precision. The accuracy of fire of our largest guns, provided with rifled bores, carefully constructed projectiles, and finely marked and delicately graduated sights, was a thing undreamed of in the days of Nelson and Collingwood. The bursting charges of our modern shells surpass in weight the whole projectile fired from the old smooth bore guns which battered the Franco-Spanish fleet at Trafalgar. Length of range has, of course, prodigiously increased, and the distance, known in Rodney's time as *random shot*, would now be regarded as an easy limit of accurate practice. The word "shell" itself has ceased to indicate but one description of projectile, and now gives a generic name to a whole class with several subdivisions. The shrapnell shell filled with its hundreds of balls, is for our newest guns, ingeniously constructed so as to act the part of a gun itself; and, when on being fired, it has attained the most convenient distance from those whom it is intended to destroy, it can pour forth a terrible *mitraille* of its own. Nor can iron plates be regarded as a secure defence against shells since Major Palliser has invented his *chilled*, or hardened, projectiles, which penetrate a thick plate, and burst when so placed as to do most damage.

Before the gun in point of antiquity, according to some before it in destructive power, and next to it, at all events, in tactical importance, is the *Ram*. The ancient mode of attack by striking at the enemy's ship with the prow of your own has recently been revived. This revival of course is owing to the general introduction of steam propulsion, and so important have been its effect, that the system of ship construction has been very generally modified since the ramming attack has again come into favor. No efficient man-of-war is now built without a prow, or beak, *vulgo* a ram, specially designed for purposes of attack. The records of accidental collisions between ships sufficiently illustrate the terrible destruction which could be wrought by one vessel purposely constructed for ramming when designedly directed at speed against another.

But the weapons for our future use in sea-fights are not those only which have been suggested by the experience of long ago. The subtle electrical torpedo has lately been added to the armaments of ships of war, and many ingenious officers are at this moment occupied in developing its destructive powers. So important do the Americans deem this weapon as an engine of destruction, that in an official report letely presented to Congress, by the Chief of the "Bureau of Construction and Repairs," that officer states his conviction that when the fact of its complete adaptability to war purposes "becomes well known, the question of building iron-clad cruising vessels will be solved." Hitherto the torpedo, whether electrical or mechanical, has been almost exclusively used as a coast defence; but now it is to form part of the equipment of our fleets. Captain Harvey, a naval officer, has devised a weapon which, by its peculiar shape, is caused, when towed from a vessel, to diverge from her side, and thus present an obstacle of formidable danger to any enemy who should approach too near. In addition to this, we are promised the use of an extraordinary modification of the torpedo, proposed by an English manufacturer and engine-builder, long resident in Australia, Mr. Whitehead. The details of this gentleman's invention have been kept secret, except from a select few; but from accounts of it which have found their way into the press, it seems to be a kind of diminutive submarine vessel, supplied with some internal motive power, and capable of itself regulating its course and direction to a very wonderful degree, and of travelling with considerable speed towards the object aimed at, on contact with which it would explode.

Offensive weapons have not, however, had it all their own way in the race for superiority over defensive armor. Thickness of plating is continually on the increase; and the plan of towing a torpedo by the side of the ship will unquestionably render the ramming-attack always hazardous and difficult, and frequently absolutely impossible. As yet, not very much attention has been bestowed upon the possibility of guarding against the destructive effect of the torpedo itself; nor have the thoughts of our officers been much turned toward the practicability of disabling by vertical fire ships which are impervious to horizontally projected shot and shell. The construction of ships on the cellular system, specially to neutralize the effects of torpedo explosions, and the adop-

tion of sea-service rifled mortars for accurate fire on the decks of vessels the sides of which are protected by armor too thick to be penetrated by any guns which there is any hope of carrying afloat, are innovations which are but just appearing above the horizon of naval invention.

As naval actions in times to come will be fought with new weapons, and between ships of a new description provided with a new motive power, it is more than probable that they will differ greatly from those of the past. From the final adoption of a numerous armament of broadside-guns, down to the last great action fought at sea, the mode of fighting, in essentials, varied but little. The great thing was to get into such a position that all the guns on one side could be brought to bear upon the enemy, and then began a game of mutual pounding, of which he, who could hold out longest, became the winner. The object of all manœuvres was to get into the above position, and, when once it had been attained, manœuvring ceased. The historian relates that, on "the glorious 1st of June," Lord Howe, when he saw the greater number of his ships "in station," "emphatically closed his signal-book," as though to show that he considered all manœuvring at an end, and that the work before his fleet thenceforth was fighting alone. "It was the height of strategy," as Captain Colomb says, "to bring our strong points against his (the enemy's) weak ones; and broadside to broadside did that in perfection." Besides, too, the masts and sails, the possession of which alone insured the power of movement to the ships, were soon damaged or destroyed, and all possibility of any useful manœuvring was thus completely put out of the question.

Hereafter the duration of the motive power and the existence of the ship as a fighting component of a fleet will end to together. The former destroyed, the latter is at an end also. A constant state of restless motion will be a necessity of future naval engagements. It should be the aim of the tactician to render that state of motion as full of purpose as possible. Suppose two hostile fleets sight each other in the midst of the Atlantic Ocean. They will probably be within sufficient proximity for actual combat in less than an hour from the moment when each first descried the other. Preparations must be rapid. No longer as in the "old war" will two fleets, of which one is to windward, cruise in sight of one another for days, one eagerly looking for a change of wind to enable it to close with its adversary. From sighting to beginning the fray will now be only a question of minutes.

The two fleets having sighted each other as we have supposed, will, probably—for here we must enter into the region of conjecture—rapidly near each other. As they approach, fire will most likely be opened from those guns (with which all efficient ships are now provided) that are mounted on the bow, or so as to fire ahead. The shots that can be fired will not be numerous. The hostile squadrons will soon be too close for "bow fire" to be of any further use; and as they get very near each other, captains will, perhaps, not care to have their view of the foe impeded by clouds of smoke hanging about their ships. Each vessel, still maintaining its speed, will not improbably look for an opponent in the enemy's force upon whom to try her "ram." The enemy, on the other hand, will most likely be preparing to do the same, and then between each pair of ships will begin a game of skill in manœuvring, to avoid not only the hostile prow, but also the torpedo which will inevitably be towed alongside. In addition to these manœuvres of defence, there will be those by which it is attempted to deliver a deadly thrust with the prow, to pour in a concentrated broadside from the best position, and also to plant the terrible torpedo beneath the opponent's bottom. Supposing the skill on both sides to be nearly on an equality, the fleets will at first pass through each other, then they will have to turn round, necessarily with circumspection, to avoid being caught in flank whilst so doing, and perform the same evolutions over again. Against disabled ships, if there are any, will be launched Mr. Whitehead's fish-torpedo, which may be regarded as the modern equivalent of that long used naval invention, the fire-ship. Ships in future will be able to carry whole squadrons of these destructive little vessels—for such they may be called—and when one fails, may quickly send another to perform its work.

It is often lamented that the introduction of steam and the consequent disuse of sails have destroyed much of the romance of the sea. The trim frigate has given place to the monitor, and the snowy canvas to the hideous smoke-stack. It will probably not

be so in future sea-fights. The excitement and the interest of them will be greater than those of former days. The old protracted cannonades from ships stationary are as much things of the past as the twelve and eighteen-pounders which contributed to them. In the old days, as we have said, all manœuvring ended when the battle began; henceforth they will begin and end simultaneously. To the interest of one of the old frigate-actions a battle between single ships hereafter will add that of a contest between two agile gladiators of the arena. Mr. Whitehead's torpedoes will require more exciting and more skilful tactics for their use, than did their prototypes, the fire-ships, which gave so much anxiety to worthy Mr. Samuel Pepys. No future Secretary to the Admiralty is likely record in his diary as he did under date of June 4th, 1666, "We fought them" (the Dutch) "and put them to the run, till they met with about sixteen sail of fresh ships, and so bore up again. The fight continued till night, and then again the next morning from five till seven at night. And so too yesterday morning they began again and continued till about four o'clock." In fights to come things are likely to be settled somewhat more expeditiously. At a recent meeting of the Institution of Engineers and Shipbuilders of Scotland, Mr. Robert Duncan, the President, in his introductory address, touched upon the question which we have been discussing. His remarks, as those of an eminent man highly qualified by his pursuits and the evident thought he had bestowed upon the subject to form an opinion, are well worth attention. After speaking of our comparative naval position, and of the means at our disposal, he said:—". . . . We have ships equal to the best anywhere else, and are beginning others superior; we have guns unsurpassed in weight and penetration, and do not mean to stop at that; and beyond that, the experience that has been acquired of the use and power of the torpedo, as an instrument of offence and defence, has demonstrated its value as a coast-guard superior to all other modes of coast-defence; while its application to the purposes of submarine attack point not indirectly to a revolution, if not to a revulsion, in the practice of naval warfare, and the feelings with which humanity is likely to regard it. Evidently the tendency of modern warfare on the sea is not to a chivalrous struggle for mastery or honor, but to a murderous one intent on wholesale destruction, alike without glory or safety; a *contest in which one, or both, of the combatants must certainly perish.* The final result of this style of warfare must be, that men will refuse to go to sea to certain death, and we shall have a repetition of the game of the Crimean and Franco-Prussian wars; the weaker, or *least prepared*, will keep in port within a torpedo-reef; and the stronger will chafe in idle impotence outside this belt of certain destruction." Naval officers may be excused for doubting that the navy has already been thus improved off the face of the earth, but they will probably derive from these remarks an increased conviction of the necessity of knowing how to attack and how best to resist.

To account for the oblivion into which the study of the art of tactics has fallen, many theories may be set up. It will be more profitable to try and rectify than to account for such a state of affairs. The intense professional conservatism of naval affairs has undoubtedly much to answer for in having kept up a belief in old methods, which should long since have passed away. Entering the service at a tender age, cut off by its conditions from frequent converse with the outer world, the repository of a knowledge shared by his fellow-seaman only, it would be strange if the naturally conservative tendency of an Englishman were not intensified by a life spent in the Navy. Mr. Cobden expressed his opinion that in their adherence to old plans, the English were not so much Conservative as Chinese. In professional matters the naval officer is often an Englishman of the English; a Conservative of a type to which the highest Chinese Tory would be a Radical of the most advanced class, fitted to take his seat on the benches of the extremest Left. Such prejudices are being now rapidly undermined, and are falling away. A misconception of the intentions of the authorities has, perhaps, conduced to the retention of them. Unlike his brethren of the Army, the officer of the Navy is precluded from discussing professional subjects in print. It is more than probable that this prohibition was only intended to include such discussions as might weaken discipline, or divulge secrets, which it was fitting should be kept. It has, however, placed the intelligent and the thoughtful on the

same level as the stupid and the ignorant, and has greatly tended to induce, or at least to maintain, a stagnation of professional zeal. In reality, the prohibition was never levelled at the discussion of all that relates to the real art and technical part of the profession; if it were, it has been so much more honored in the breach than the observance, as to be practically repealed. At least we may say, as old Pepys did on the last day of the year—"but I hope all things will go well, and in the Navy particularly, wherein I shall do my duty, whatever comes of it." We may be sure that many a naval officer who never read a line of Mr. Pepys's diary has often expressed the same hope and the same determination.

All questions of improved efficiency of our defensive forces must sooner or later be investigated as to their probable cost. It is almost certain that much valuable information might be obtained at but a trifling increase of expense. The wise custom of the last three or four years has collected in "combined squadrons," the commands of several flag officers. Much improvement in the evolutionary knowledge of our officers has been the result. The additional cost of a few days' tactical experiments would not be very enormous; it would amount, probably, to about one-twelfth of the loss of the purchase and re-sale of the extra horses required by the Control Department of the Army at the late manœuvres; no very extravagant price to pay for knowledge which might prove inestimable. The Russians, to whom we owe the origin of so many panics, have thought it worth while to expend some tons of extra coal in trying experiments of the kind. The British Navy ought scarcely to lag behind that of the Czar in progress. It should be remembered that it is a force, which, amongst navies, holds a place of even more undisputed pre-eminence than does the Prussian Army amongst armies. It is almost universally looked up to and copied from its most important details down even to the fashion of its buttons and gold-lace.

ARTIFICIAL FUEL.

From the "English Mechanic."

It is a curious and interesting circumstance, that, so far back as the latter end of the reign of Queen Elizabeth, when wood was plentiful and coal but little used, an attempt should have been made to produce artificial fuel for use in the open hearths of that day. About the year 1594, Sir Hugh Platt tried to introduce into general use in England a mixture of coal and loam, according, as he states, after the "manner of Lukeland, in Germanie"—wherever that place may be. He used other mixtures, such as sawdust, tanners' bark, cow dung incorporated with small coal, and cemented together with his favorite loam. This is, I believe, the first known attempt to manufacture "artificial fuel."

Curiously enough, it contains the elementary idea of such mixtures suggested up to the present time. All, or nearly all, the schemes that have been produced set out with the basis of small coal, or pit waste, and mix it with all kind of combustible matter, and cement them together in blocks, or cakes, for ordinary use as a cheap substitute for coal—even when, as we know, that wood was plentiful and sea-coal but slowly coming into general use. At this early period, then, the waste of small coal had attracted notice. After Sir Hugh Platt's laudable attempt, the idea seems to have slipped out of sight, and for nearly two centuries little or no attempt was made to carry on the process.

It was not till the first year of the present century that attention was drawn in any marked degree to the matter, when a patent was granted in which small or refuse coal was mixed with charcoal, wood, breeze, tan, turf, sawdust, corkcuttings, peat, and other inflammable ingredients. All these, or any of them, were to be well mixed and incorporated together, and then partially carbonized in kilns or ovens, to expel any moisture, the heat being so regulated as just to cement the materials together into one compact mass without destroying any of their combustible properties. This system may be taken as the type of pretty well all the other schemes followed out by adventurers in this proposed line of industry and hoped-for economy. It will be seen at once that for a large scale of production many of the articles introduced could not be obtained in

regular supplies at a cheap rate—for tan, corkcuttings, and sawdust would be limited in quantity and irregular in supply—so that in the long run any hope of cheap fuel from such a source would terminate in hopeless failure.

It is quite useless to look for cheap fuel being obtained from materials which depend on supply from the waste or refuse of any kind of manufacture for the necessary production of such materials. The supply must be very inadequate to meet the enormous demand for such an article as fuel, where, to be of any use, millions of tons would be required. All these kinds of attempts may therefore be dismissed as being out of court and of no practical avail. We must depend more or less on natural sources of supply, and endeavor to combine them in the cheapest and most efficacious manner. Nor can the manufacture of a reasonably cheap artificial fuel admit of much extraneous aid from expensive labor and complicated machinery; these are to be avoided as much as possible.

We now come to another series of attempts in what was called the preparation of "Gaseous Coke"—a specious and deceptive term, well adapted for leading enthusiastic experimenters into endless perplexities and profitless disasters. Here the object aimed at was to convert small coal by the addition of coal-tar, either in a pure state, or mingled with naphtha, and the other ingredients in which it is generally found combined, into a well mixed mass. It was then to be put into a suitable oven, and sufficiently coked to cement all the materials together, to be afterwards broken into suitable blocks for use.

This partial coking is the leading idea of many attempted experiments, and runs through many patents. Numerous schemes were brought forward to obtain cheap fuel by this method of procedure, but as they all more or less involved the previous manufacture of their most essential ingredient, coal-tar, as might have been expected, the anticipations of the numerous projectors were not realized, and led to barren results.

In the year 1823 a step was taken in the right direction, by the simple employment of two of the most abundant of the real raw materials of fuel, making the cheaper assist the most costly. In this attempt bituminous coal of good caking quality was mixed with culm, or the small of stone coal, or anthracite, these being mixed together in definite proportions, and then converted into a kind of soft coke in ovens in the usual way, by a partial carbonization. The anthracite was broken small and mixed with a proportion of small bituminous coal sufficient in quantity to make a good freely-burning coke. As far as I am aware, this is the first time in which anthracite is proposed for the purpose. This appears to have been the first rational attempt in really the true direction to combine two abundant raw materials, and if properly carried out might have produced a moderately priced article, useful in times of coal-dearth like that now existing. It might, perhaps, be much improved in combustible quality, by the addition of a small quantity of the common mineral or earth oils now so abundantly found in many parts of the world, the existence of which at that time was scarcely known. The basis of this plan was of course to enrich the poor anthracites by the bituminous qualities of better coal, and thus obtain a useful material adapted for ordinary purposes.

After this time small coal was combined with lime, clay, marl, blue clay, river silt, or deposits made in stagnant water, and all kinds of earths in general. These were to be broken up small, mixed together, and receive a dose of tar and sufficient small coals to give the mass enough consistency to admit of its formation into cakes, to be afterwards dried by air, or by artificial heat. The result would be a poor material blessed with a minimum amount of combustible virtues, and liable to crumble to dust, unless blended together by carbonization like the rest.

About the year 1836, a new and attractive field of investigation and experiment was opened up to the delightful eyes of speculators and experimental inventors. Attention was forcibly drawn to the vast quantities of moss, bog, and peat, lying comparatively idle, and many efforts were made to utilize this really valuable material as a ready means of producing cheap fuel —good in quality and abundant in quantity. For this purpose peat-earth, bog and moss, slimy, or any other kind of vegetable earth, were mixed up together, in some cases simply compressed and sold as turfs —in others mixed with nitre, alum, rosin, linseed, green vegetable matter, animal excrements, and similar materials—all these were to be ground up together in

mills, pressed into moulds, then dried by heat, and in some cases partially coked.

Here it will be perceived for the first time that we enter more or less into the domain of chemistry, and such ingredients as nitre and alum are brought into play, to be followed soon after by an endless variety of chemical compounds to facilitate combustion in the more refractory materials employed. In addition to the ordinary bog earth, moss, and peat, a long list of other vegetable materials are enumerated, from the bark of trees down to fruits, shells, and seeds.

We are gravely informed that the bituminous, resinous, and oleaginous substances are to be boiled, distilled, or dissolved, so as to separate the solid from the liquid parts, then all are to be mixed together, in some cases simply pressed, in others to be agglomerated together by heat—altogether a very pretty process, got up regardless of expense—a sure and certain way of not creating cheap or useful fuel—a consummation most devoutly to be wished in the matter of peat.

It is clear that every such process of cutting, grinding, mixing, moulding, boiling, distilling, and dissolving would add too much to the cost of the raw material—plentiful as that may be,—and that consequently the production of a cheap artificial fuel was impossible by any such elaborate means.

A great variety of costly machines, of more or less complexity, were invented and brought forward for every kind of purpose connected with the much-wished for utilization of peat, for cutting, drying, grinding, and compressing, with various degrees of success, some of which are in operation at the present time. To these may be added a few machines for the purpose of aiding in the introduction of chemical compounds and combustible substances into the peat and turf, which were to yield oxygen, and heighten the heat of fuel thus prepared; but little or nothing came of these fanciful combinations; they looked well enough on paper, but were of little use, and no profitable results appear to have followed their introduction.

Another plentiful variety of schemes had for their origin the idea of converting peat into coke by means of slow combustion in suitably prepared ovens, thus distilling away many of its most useful properties; the peat coke so prepared was then to be ground to powder, and as before, in many other cases, to be mixed with pitch, tar, rosin, or any other bituminous matter in a melted state, then ladled into moulds, and dried ready for use. This was, with little or no variety, the ordinary process adopted by many enthusiastic projectors, who overlooked altogether the cost of so many operations. The question of utilizing peat or bog is a very interesting and tempting one, but would occupy too much space for discussion in these brief notes.

Another series of speculations now came into favor for a time, the ruling idea being to get hold of any material naturally spongy and porous, or that could be made porous by heat or partial calcination. These partial and imperfect combustibles were to be made use of by filling up their pores with inflammable matter, like spirits in a sponge, and thus it was sanguinely hoped to produce a cheap and plentiful fuel. For this purpose lime, chalk, clay, brick-earth, porous stones, or any earthy substances which in their nature are capable of being saturated with tar, resin, oily and fatty matter, or hydrocarbons and similar materials of the kind were employed. The porous materials had to be saturated with the combustible materials, allowed to harden, and so in due course became ready for use. In other schemes peat fibres were to be actually glued together by the application of starch, gluten, glue, size, wheat paste, and similar articles, to cement the fibres together—a very sagacious plan, worthy of the wise men of Gotham.

It is not necessary here for any practical purpose to go through a pretty long list of abortive attempts to introduce a greater variety of purely chemical means of creating artificial fuel than has been previously alluded to. As a mere matter of curiosity, it may be stated that the following chemicals have been freely employed as mixtures to facilitate the combustion of artificial fuels: Chromate and chlorate of potash, alum, rock-salt, nitrates of soda, potash, and alumina, nitric and hydrochloric acids, hypochlorate of lime, sulphuric acid, hydrochlorate of manganese, chloride of manganese, carbonates of soda and magnesia, binoxide of manganese, oxide of iron, ferricyanide of ammonia, acetates of iron and alumina. This long array of chemicals is quoted in order that the reader may judge for himself of the probability of any satisfactory result

being obtained from such an amount of complication and science run mad.

Little or nothing came of any of the schemes in which this sort of chemical science and materials were involved, so that elaborate and fancy dreams of this nature may be safely neglected, being impracticable and unprofitable on the scale required for the production of fuel for the common purposes of every-day life.

Proposals were also made for utilizing the waste heat from ordinary cooking ovens. For this purpose a series of close ovens were placed immediately over the common cooking ovens, so that the small waste coal filled into the upper close ovens or retorts was sufficiently softened by the action of the waste heat to bind the loose coal into a compact mass; it might then be withdrawn, put into moulds, and pressed into blocks by any of the ordinary means in use for that purpose. This method of utilizing waste heat and small coal might be successfully applied at any considerable coking establishment, such as is now used by every railway company for the manufacture of coke. A patent for the above process was granted to F. Neville, in the year 1838, and forms the basis of several others for similar purposes.

In 1845 Frederick Ransome turned his attention to artificial fuel, and introduced a plan for cementing together small coal by means of a solution of silica dissolved in caustic soda, the small refuse coal so treated to be then compressed into blocks suitable for use. In the year 1849 Henry Bessemer devoted some time and attention to the matter and proposed simply to heat small coal sufficient to soften it, and thus render it capable of being easily pressed into moulds and formed into solid blocks.

The coal, according to this plan, might be softened either by the action of steam or in suitable ovens. Coal alone was used; no extraneous matter of any kind being employed. This is a well-devised scheme, at once simple and efficacious; the waste steam from the pit-engines might be used for the purpose, or conveyed to a small boiler and re-heated at any convenient place near the spoil-banks of waste coal.

Frederick Ransome, in the year 1856, brought forward one of the most simple and efficient plans yet devised for the purpose of converting loose small coal into solid blocks at the least amount of trouble and expense. For this purpose the loose small coal is to be placed in suitable moulds, then to be passed into an oven or retort, and is to be just sufficiently heated to cause the loose coal to agglomerate into a compact mass, at once ready for use on being cooled. In this simple process, like that of Bessemer, nothing but the pure coal is employed, being entirely free from foreign admixture or adulteration by any other ingredient, and not so highly carbonized as to be converted into coke.

With suitable heating-ovens or furnaces, this appears to be about as economical a plan as any out of the many yet devised, and such ovens may be readily erected near a pit, and thus daily utilize the waste small coal as it is produced, without employing for heating the moulds a single scrap of marketable coal; it is therefore admirably adapted for the purpose contemplated.

Another idea put forward was that of bringing "all natural coals to a uniform standard of combustible power," by artificial means, increasing the heat-giving power of indifferent coals by the addition of definite proportions of coke, resin, napthaline, and pitch, and similar matters, so as to render them equal in combustible strength to the best coals. This system has been hinted at before, but it appears to involve too many processes to render it of any very great economical value on a large scale of operations.

As before remarked, many attempts have been made to improve the quality of the steam-coal or anthracite, and render it suitable for ordinary domestic purposes. John Blythyn employed 84 per cent. of anthracite mixed with five per cent. of any good bituminous coal and 5 per cent. of coal tar; to this mixture 5 per cent. of water is added. After being well incorporated together it is to be put into moulds and heated to a pulpy condition, care being taken to guard against the escape of any of its gaseous materials. It is asserted that this artificial fuel does not emit any smoke—a very desirable quality, if true.

Combinations of small coal and lime in different shapes are numerous; and James Shaw proposes to use waste coal, to which is to be added one-fourth of its bulk of lime, which are to be thoroughly incorporated, then to be slightly moistened—in fact, made into a small coal concrete; then, of course, come the inevitable moulds to form the blocks. He states that this preparation gives a more intense heat at less cost, and

will last considerably longer than any ordinary coal. Some prefer to use the lime in a slacked state, some quick-lime; any compound containing lime may be used; and some more simple-minded or more ingenious than others gravely propose to dip their artificial blocks into a cream of lime, and thus dress them up in a summer attire of creamy white.

Some inventors of a more facetious turn of mind appear to have drawn their ideas of preparing artificial fuel from cookery books; here is a specimen proposed by a gentleman of this lively class, evidently of very sanguine temperament. He says good artificial fuel may be produced from limestone, slate, or other stones, which become porous when properly treated; when calcined to perfection, they are to be turned into a boiler, and then boiled with gas-tar, pitch, or bitumen; then, by way of sauce piquante, there is to be added a decent dose of paraffine, naphtha and other liquid fuel, which so far completes the cookery; and nothing now remains to be done but to pop the precious compound into ornamental moulds and serve up cold. We have seen that Ransome proposed to cement small coal together by means of a solution of silica in caustic soda; whilst, by a reverse process, another inventor proposes to make artificial fuel which shall really be "nothing more than petroleum solidified by coal dust"—a very handy compound, no doubt, and possibly well adapted for lighting fires instead of sticks and paper. He makes no allusion to the more pungent than elegant perfume emitted by raw petroleum and the Stygian smoke thereof.

Not long since I received a letter from my excellent friend Monsieur Dot, of Ottawa, Canada, asking if it was not possible to utilize the immense quantity of sawdust perpetually accumulating in that rising city. It seems that the quantity of sawdust in that place accumulates so fast at the saw-mills as to become a nuisance even to the extent of choking up the river and poisoning the fish.

Here, then, is a raw material brought in the shape of timber from the backwoods, and converted into a deal of dust by the relentless teeth of the never-ceasing saws in the lumberers' yards. Well, there is no making a silk purse out of a sow's ear—but sawdust can be made into coke or charcoal—the method has been propounded often enough in England; why not try to carry it into practice in Canada, and thus convert the nuisance into a utility—into fuel in fact?

In the year of grace 1860, Herr Ludwig Buckholtz proposed to carbonize sawdust or any other finely divided vegetable substance; to effect this purpose he placed the sawdust in a closed vessel, and passed through it a current of hot steam, thus expelling the air and aqueous vapor, then the carbonization is carried on by heat from the fire in the usual manner. If steam is not handy the sawdust had better be dried beforehand. The apparatus employed was a vertical retort containing a smaller perforated vessel, which can be charged from the top; at the bottom end, on opening a slide, the charcoal falls into a close receptacle beneath.

This may be useful among the large lumber establishments of Canada and Russia, where vast quantities of sawdust are produced, as well as Norway and Sweden.

Another mode of converting it into fuel is by combining with the sawdust, chaff, chopped straw, bark, strippings, or any similar material, then mixing them with melted resin, pitch or gas-tar, all plentiful in Canada, blending them together in suitable proportions, moulding into blocks, and drying for use. Sawdust dried is mixed with resin, in small quantity, and pine-oil—a little melted resin is then poured in, the the whole well mixed and moulded while hot; a small quantity of nitrate of soda or potash may be thrown in to increase its combustion, and it may then be easily utilized as common fuel to boil the pots of the lumberers. Vegetable charcoal may be made from wood sawdust, by being acted on and carbonized by sulphuric acid and water; the acid liquor is filtered off, and the charcoal-powder compressed and dried.

These are the ideas of separate men who have turned their attention to utilizing sawdust, so that Monsieur Dot and the good people of Ottawa, with these hints, may boil their kettles out of what has hitherto been a growing nuisance. "Faint heart never won fair lady." So, Monsieur Dot, be of good cheer, and work up your mounds of sawdust into fuel for the winter.

In bringing this brief resumé of the different processes followed in the proposed production of artificial fuel to a conclusion, it will be seen that the first and simplest principle is that of merely compressing the loose particles of small coal

into blocks. The second, that of combining the waste coal with water and pressing it into blocks; this I have seen successfully practised at the mines of Bedarieux in the south of France. Then comes the admixture of foreign combustible, or partially combustible materials, with the small coal; after these come the admixture of oils, fats, petroleum, and hydrocarbons in great variety; followed in due course by the introduction of what may be termed pure chemicals, already sufficiently alluded to.

Cheap artificial fuel, made from waste or refuse materials, still remains a desideratum, and is quite open for the active enterprise of men of energy and ability who have a practical knowledge of the nature of fuel, and the whereabouts of the necessary raw materials. It must always be borne in mind that little benefit or real good can result from any effort, unless such fuel can be made on a large scale; for the supply will have to be estimated by millions of tons.

It seems almost as if we shall have to go back to the early ideas of worthy old Sir Hugh Platt, and make considerable use of marl, as he first proposed in the days of Queen Bess, with lime and chalk, to be rendered more or less combustible by the admixture of small coal and peat, leaving aside the more fanciful combinations of pure chemistry.

Many proposals to cheapen the production of fuel, at the present time of high prices, are suggested in the daily journals, recommending, in most cases, the application of small quantities of tar, rosin, and similar substances, to assist in the more perfect combustion; but something more than this makeshift is required, to convert a temporary effort and hand-to-mouth scheme into a practical, useful, and permanent source of fuel supply. A judicious combination of waste coal, authracite, lime, marl, etc., may yet be found, by diligent inquiry and experiment, to produce a fuel of fair quality and reasonable price; but such experiments for the purpose should be made at the works, and not merely in a comfortable laboratory. Perhaps these few gleanings may be the means of drawing attention to this, now more than ever, important matter, and revive intelligent inquiry in to the whole bearing of the interesting subject of cheap fuel.

THE SPECTROSCOPE SIMPLIFIED.

[We gladly publish the following communication from a scientific gentleman of a neighboring city.—Ed.]:—

Mr. Editor,—For the last few months I have been engaged in a series of investigations by means of the spectroscope, in the prosecution of which I have discovered some very simple means of producing results that have hitherto, so far as I am informed, required more or less complicated and expensive apparatus. In arranging a small compound prism for the purpose of constructing a direct-vision spectroscope I was surprised to find that the prism *alone*, without slit, collimator, or observing telescope, gave me, by direct sunlight, a distinct view of all the principal Fraunhofer lines. So sharply were they defined that I could easily resolve the *b* group. My first impression was that this result was attributable to the peculiar construction of the compound prism, but a little reflection convinced me that the same results, in greater or less degree, might be obtained from *any* prism, and I immediately proceeded to test the truth of this conclusion. I found that any ordinary dense flint prism of 60 deg. would give similar results. It is not limited, however, to prisms of any particular material or angles. With two prisms of 60 deg., filled with bi-sulphide of carbon, very fine results may be obtained, and the components of the D line made distinctly visible to the naked eye. The most satisfactory mode of arranging and using the prisms is as follows:—A beam of direct sunlight is made horizontal by means of an ordinary mirror, and from this the ray is received upon the face of the prism at an angle to the perpendicular of as near 90 deg. as possible. This would give the angle of maximum deviation to the emergent ray, and owing to the peculiar manner in which the light strikes the prism, gives the main Fraunhofer lines without the aid of slit or collimator. It is much more satisfactory, however, to use *two* prisms, in which case the second one is placed so as to receive the mean ray from the first prism at the angle requisite to produce the

angle of minimum deviation. With one prism, it is easy also to obtain the principal bright lines of colored flames, but in this case the bands will be somewhat curved owing to the divergency of the rays. The lines can, however, be produced nearly straight by placing the flame at a distance from the prism. The prism then is of itself a *spectroscope*, a fact of evident value to those whose facilities and appliances for this kind of work are limited.

Following the same course of inquiry, I found that the *diffraction plate* gave me similar, but much more striking results. By receiving the ray upon the plate at the greatest possible angle the naked eye readily detects the Fraunhofer lines. In the spectrum of the 2d, 3d, 4th, and 5th orders the components of the D line are readily resolvable, and with an observing telescope of a power of finer diameter, the nickel line is easily seen in the spectrum of the 5th order. These facts are, so far as I can learn, entirely new. The production of a *pure spectrum* has been, by all writers and workers, considered as dependent upon the slit. Only one author that I have examined, Helmholtz, recognizes the fact that a *pure spectrum* can be obtained at the angle of *maximum* as well as that of *minimum* deviation, but he does not recognize the fact it can be obtained by the prism alone.

A. K. Eaton.

P. S.—Since writing the above I have attached the diffraction plate to the telescope of the Packer Institute Observatory, and, using a collimator alone, but without an observing telescope, obtained a fine view of the red prominences by the naked eye.

A. K. Eaton.

REPORTS OF ENGINEERS' SOCIETIES.

American Society of Civil Engineers.—A regular meeting of this Society was held at the rooms in New York, March 5th, 1873.

A paper on "Shaw's Gunpowder Pile-driver," by Samuel R. Probasco, C. E., of Brooklyn, N. Y., was read.

This pile-driver was set at work in October, 1872, on a line of sheet piles for a reservoir dam in the valley of Parsonage Creek, Long Island. The material to be penetrated was sand and fine gravel, cemented together in places so as to be hard and difficult to move with a pick, and like "hard pan." Clay was found below the water level of the basin; some borings showing it at 15 ft. below the surface; the lower stratum was tough and tenacious, and the whole material was under water.

The machine in form resembles an ordinary pile-driver; a cast-iron block called a "gun," resting on the head of the pile, is bored out, and receives without windage a wrought-iron piston attached to another cast-iron block called the "ram," which is lifted by explosion of powder in the bore. When the piston leaves the gun a cartridge is thrown in, which, exploded by the heat freed by the piston in its descent, throws the ram upward again, and forces the pile downward. The area of the piston is adjusted to the weight of the ram, which also is adjusted to the work to be done. Soda powder cartridges in cylinders of 1¼ to 1½ oz., coated with black lead and paraffine, are used. The coating is expected to keep the powder dry, lubricate the gun, preserve the requisite tightness, prevent escape of gas, and cause the entire force to be exerted on the base of the piston.

The piston is made a little smaller than the bore of the gun, and has on its lower end a steel ring, which fits the bore closely. The performance was as follows: At first several explosions were necessary to lubricate the gun, which leaked gas so that the ram would not go to the requisite height to move the pile. After a few shots the piston moved up regularly, and in its descent fired the charge, forcing the pile down and itself upward. When the resistance is slight this machine may be economical, but when, as in this case, it required 300 blows from cartridges costing 2½ cents each to force a pile down 15 or 16 ft., it cannot be called so. The gas from the explosions cut passages in the ring at the end of the piston, and thereby much lessened the power of the machine. The gun became hot from the rapid discharges, and the bore enlarged, whereby more gas escaped; 7 piles were driven with it—each costing more for powder than the contractor got for piles in place—when the machine refused to work. On examination, the steel ring was found furrowed by the powder, and the piston (diameter 5 in.) so bent by striking the bottom of the gun, as to be useless. The air cushion relied upon to prevent this was lost by the furrowing of the ring. The inventor on being consulted decided that the excessive consumption of powder was due to the piston being too small for the ram, weighing over 1,700 lbs. The bore of the gun was then enlarged to receive a piston 7 in. in diameter, and 10 piles more were driven, when the machine was again laid aside. The result of this trial was similar to the first, except that the piston was not bent. The gun got so hot as to fire the powder before the ram reached its place. Altogether 17 piles were driven to a depth of from 14 to 19 ft.; requiring from 200 to 300 blows of 1¼ oz. cartridges. An ordinary pile-driver was then employed, with a hammer weighing 1,800 lbs. and falling 8 to 10 ft. In this way 11 piles were put down 15½ ft. in 10 hours—costing per pile no more than 100 blows from the powder machine. These 100 blows, at best, would put the pile down but 10 ft.

The piling was spruce, from 10 in. × 10 in. to 10 in. × 14 in.—20 ft. long—with 2 in. square tongue and groove.

The piles were bevelled at the point on three sides, leaving the grooved side untouched. The groove was driven on the tongue of the preceding pile. The heads were protected with a light band. 7 piles were driven without shoeing, the eighth

split and showed the necessity of protection at the point. A cast-iron cup shoe, weighing about 40 lbs., with a groove in it, and made with three bevels and one plain side, was found to stand the work. The tendency of the tongue of the pile to work up was obviated by twisting a chain tightly about the pile and tongue; a lever with rope attached was used for this purpose, the force being applied as the blow was delivered; 75 piles were driven in this way to a mean depth of 15½ ft. By experience 6 in. more depth has been attained, which is about the maximum penetration in this kind of material, and this can only be done with the best of sound, dry spruce.

A brief discussion followed, after which a paper on "Rail Economy" by C. P. Sandberg, C. E., of London, England, in reply to the discussion had upon a former paper of his on the same subject, was read.

In that discussion it had been remarked under the head of "Traffic Capacity" that the weight on locomotive driving wheels, stated therein, differed from American practice—that on the Philadelphia and Reading Railroad, 4 tons on drivers were not exceeded for a 64 lb. rail, and that on the Erie Railway 5½ tons had been found too much for a 70 lb rail.

Mr. Sandberg herein replied that it would be interesting to know what weight the rail and the rail joint would carry in the two instances mentioned; 6½ tons on drivers on a 60 lb. rail, as stated in the table, and considered excessive, might not be so; the table showed that the 60 lb. rail of standard section with fish-plate would carry 14 tons in the middle between 3 ft. bearings, and 9½ tons at the joint between 2 ft. bearings. According to the table the maximum load on drivers on standard sections was one-third what the rail in the middle would carry, and two-thirds of what the rail-joint would sustain. In order to obtain the full value of the material, the joint ought to be as stiff as the middle of the rail. For this it is best to use the fish-plate as thick as will not interfere with the tyre flange; the angle should be as small as will permit an easy rolling of the rail. This angle is 11 deg. and 15 deg., the latter for light rails, experiments having proved that the smaller the angle, the stiffer the joint. With this fishing, the capacity of the rail at the joint is two-thirds that at the middle, while with ordinary fastenings it is but ¼. In regard to the Erie sections, experiments have shown that this rail will bear at the joint but 2 tons, while at the middle it will carry 10 tons; hence it is not strange that 5½ tons on the drivers proved disastrous. The necessity of sufficient thickness in the fish-plates is often overlooked. It is doubtless prudent to increase the number of drivers on American roads, but the statement that 6½ tons on a 60 lb. standard rail section with standard fastenings, is excessive, should be modified. This load is not the most economical for working a line, but that to which an increase of traffic might extend.

Many European railways with a 70 lb. section have a joint carrying only 6 tons, owing to too large an angle and too thin a fish-plate.

INSTITUTION OF MECHANICAL ENGINEERS.—The general meeting of members was held on May 1, at the Institution of Civil Engineers, London.

Mr. C. William Siemens, D. C. L., F. R. S., President, in the chair.

The Secretary (Mr. W. P. Marshall) read the minutes of the previous meeting, and the election was announced of a number of new members.

The first paper read was "On the Allen Governor for Steam Engines," by Mr. Frederick W. Kitson, of Leeds, which is the invention of Mr. Huntoon, of Boston, United States, and consists of a small paddle wheel, driven by the engine, and revolving at a high speed within a cylindrical casing partly filled with oil, the casing being free to turn loose upon the paddle-wheel shaft. Projecting ribs inside the casing come nearly into contact with the revolving paddles, and the resistance to the passage of the oil causes a tendency in the casing to rotate with the wheel, and this is counteracted by a weight that is suspended from the casing and wound up by any rotation of the casing. The weight is adjusted to balance exactly this rotative force when the engine is running at its proper speed, but when that speed is exceeded the weight is overcome and drawn up, or, if the speed falls off, the weight at once drops. The weight is connected to the level of the throttle-valve, so as to shut it when rising, and thus prevent increase of speed of the engine, or to open the valve when falling, admitting the required steam for maintaining the speed. In the event of any reduction in the load upon the engine, however sudden, the governor is instantly adjusted accordingly by the weight being wound up until the throttle-valve opening is reduced to the proportionate area required for driving at the same speed with the reduced load, and with any increase of load a corresponding change of position takes place. This governor has been in use nearly a year on several engines at the writer's works, and in one of these driving a steel tyre rolling mill, an increase of 460 horse-power suddenly takes place, and is suddenly thrown off in the course of the work; this governor is found to control the engine completely, without any change of speed being perceptible, the stop valve being left full open throughout. This governor is driven by gearing, so as to avoid any risk of accident from a belt slipping. With the ordinary Watt governor previously used in this case it was necessary for the engineman always to stand by the throttle-valve, and handle it whilst rolling a tyre, to prevent the engine being pulled up by the increased resistance, or running away after the tyre was rolled. In order to prevent any tendency of the governor to over-run when changing its position the weight is suspended from a spiral, which increases its leverage when wound up to the highest position, and diminishes its leverage at the lowest position, so as to cause the governor in each case to return at once to its correct position. The means of readily changing the working speed of the engine is given by adding or removing a portion of the suspended weight, which is made in segments for this purpose. A balanced throttle-valve is employed with this governor, consisting of a hollow double-beat valve, which has the two seats cylindrical and of equal diameter, and offers very little resistance to any change of position, and the governor is connected directly to it by a pinion working into a toothed sector. The governor is at work at several ironworks, paper mills, and cotton mills, and is found to work without

any trouble in keeping in order or maintaining the oil supply, and to give very satisfactory results. A working model of the governor was exhibited, together with specimens of the separate parts of the throttle-valve.

The next paper was "On Wenham's Heated Air-Engine," by Mr. Conrad W. Cooke, of London. Of the many attempts that have previously been made to employ the expansion of heated air for producing motive-power the most important in practical results were those of Stirling and Ericsson, in each of which the air was heated in a closed vessel over a fire. But the low conducting power of air rendered this a very imperfect mode of heating it, and the extensive repairs necessitated by the burning out of the bottom of the heating vessel caused Stirling's engine to be abandoned, after having driven the work of a foundry for three years. In Cayley's heated air-engine, which was a previous invention, the fire was enclosed in an air-tight chamber, and the air for working the engine was pumped in partly below the fire for supporting combustion, and partly above the fire, mixing with the products of combustion, the whole of which was passed through the engine; this plan has an important advantage in the direct mode by which the air is heated. In Wenham's engine the same principle is employed, with the distinctive feature that no separate air-pump is employed for compressing the air, this being effected at the top of the working cylinder by increasing the clearance space and making use of the cushioning for the purpose. The engine has a single-acting vertical cylinder, the upstroke being made by the pressure of the heated air below the piston, and the engine is carried through the downstroke by the fly-wheel. The external cold air, admitted by an inlet valve into top of the cylinder during the downstroke, is compressed during the first half of the upstroke, and is then delivered during the remaining half stroke through a weighted valve into the furnace chamber; the delivery passage is divided into two branches, one conveying a small portion of the air beneath the fire-grate for maintaining the combustion, while the greater part of the air is conveyed by the other passage into the upper portion of the furnace chamber, above the fire. A swing valve at the junction of the two branch air-passages determines the relative proportion of air delivered through each, and this valve being controlled by the governor of the engine regulates the supply of air to the fire, and consequently the combustion of fuel, exactly in proportion to the work done by the engine. From the furnace chamber the heated air, mixed with the products of combustion, is admitted by a lifting valve into the bottom of the working cylinder during the upstroke, and in the downstroke it is discharged into the atmosphere through an exhaust valve, these two valves being opened alternately by a cam on the fly-wheel shaft, and closed by a spring. The furnace chamber is of cylindrical shape, lined with a thick wall of fire-brick containing a number of highly heated vertical flues, through which the products of combustion pass, causing a perfect combustion of smoke; the central part of the furnace is filled from the top with a charge of fuel sufficient to last throughout a day's working, and the furnace is then closed air-tight both at the top and bottom. The working surface of the cylinder is protected from exposure to the heated air and products of combustion by a protecting drum below the piston, adopted from previous air-engines, which nearly fills the diameter of the cylinder, and is of greater length than the stroke of the piston; and any dust entering the cylinder is blown out at the exhaust from the bottom. The piston is lubricated with a dry plumbago powder, and in practice the cylinder is found to maintain a good working face, and to be as durable as those of steam-engines. This air-engine has proved very successful for cases where a small amount of power is required, and has the advantage of working for long periods without requiring attention for firing or for the engine, and with freedom from the risk of explosion or fire attending the use of a steam-engine. One of these engines was shown at work in the neighborhood.

MECHANICAL STOKING.—At the meeting of the Society of Engineers on Monday (Mr. Jabez Church, President in the chair), a paper on charging and drawing gas retorts by machinery, was read by Mr. J. Somerville, of Dublin. The author first referred to the necessity that existed for the adoption of machinery in this respect, on account of the exhausting and demoralizing nature of the work of gas stoking, and also in consequence of the strikes amongst gas stokers, of which the recent strike in London was a notable example. The first attempt at mechanical charging was made by Clegg, who had fed coal dust on to an endless iron web revolving through the retort. This method was tried, but proved a failure. Brunton in 1840 endeavored to carry out the same principle, but being defective, failure again resulted. The first attempt at direct steam stoking was made by Michael, who used an apparatus running on rails in front of the retorts. Coal was fed into the retorts at the top from wagons running on overhead ways, and the coke was pushed out at the opposite ends of the retorts. The arrangement, however, was cumbrous, and did not come into practice. Mr. Green, of the Preston Gasworks, has the credit of being the pioneer in mechanical stoking, inasmuch as the apparatus designed by him (but which was not carried out in practice) has served as a model upon which all subsequent machines have been based. The Best and Holden machine, next described by the author, was first tried at the Horseferry Works of the Chartered Gas Company. In 1867, on account of strikes, it was introduced into the Alliance Gasworks, Dublin, of which Mr. Somerville is the engineer. By it the retorts were charged and drawn at the rate of 60 per hour, or three times as quick as by manual labor. Mr. Holden has since introduced a new feature into this machine at the Beckton Gasworks, where it is worked by an endless wire-rope and a stationary engine. Dunbar and Nicholson's machine was then described, the author stating that it had been tried in London, but had not been adopted; it was complicated in its construction. Working Best and Holden's machine at his gasworks gave the author an opportunity of seeing its defects. He, therefore, designed another machine embodying improvements upon the other. He uses two separate machiness, one for drawing and another for charging, the retorts being served at both ends, and the machines following each other up in their work. The author gave the results of working by these machines, which showed

that the cost of carbonizing coal was 6d. per ton with the machines, and 1s. 1½d. by manual labor. This was taking the price of labor in Dublin, but by adopting London rates of wages in the calculation the saving effected would be much greater.

IRON AND STEEL NOTES.

SURFACE-HARDENING STEEL.—The action of rubbing surfaces moving at a high velocity is proposed to be applied to the surface-hardening of steel, by Mr. G. Armes, Rochester.

This invention has been patented, and consists in hardening the surface of steel without hardening the body thereof, by subjecting the surface of the steel to be so hardened, while in motion, to the action of a surface in contact moving at a very high velocity.

If, for example, it be desired to harden the surface of a cylinder made of steel, the cylinder is mounted in a lathe turning at the slow motion usually given for turning such a body in the usual engine-lathe. To this is applied an emery wheel rotating at a velocity of about 1800 revolutions per min. The periphery of the emery wheel is kept in contact with the surface of the cylinder, which, in addition to its slow rotary motion, has a traversing motion of a little less than an inch to each revolution. At the end of this operation the entire surface of the cylinder will be hardened to a depth of about $\frac{1}{20}$ in., and so hard that it will resist the action of the best tools made of cast steel and hardened in the usual way.

Better results, it is stated, can be obtained when the emery wheel can be run at a higher velocity than that above given; and cast-iron wheels with smooth faces, or hard substances, may be employed in lieu of emery wheels.

For hardening flat surfaces, the piece of steel should be mounted in a carriage so that it can be moved forward, in order to present in succession every part of the surface to contact with the periphery of the wheel; or the same result can be produced by mounting the wheel in a carriage having the required traversing motions. Or if the surface to be hardened be of greater width than the face of the wheel, the block steel may be mounted on a carriage having one motion, and the wheel also mounted in a carriage having a motion at right angles to the motion of the block-carriage.

If the surface to be hardened be of any form than a cylinder or flat surface, the form of the periphery of the wheel or the motions to be given, other than the rotary hardening motion, must be such as to present in succession every part of the surface to the action of the wheel.

The process can obviously be applied to the hardening of the surface of any article made wholly or in part of steel, unless the surface be so irregular that the required motion for contact and action cannot be attained or effected.

UTILIZATION OF BLAST FURNACE SLAGS.—The paper on this subject by Mr. Charles Wood, of the Tees Ironworks, Middlesborough, was illustrated by a model of the slag-cooling machine which it was intended to describe. The machine is intended for two purposes. Firstly, to cool the slag as it flows out of the furnace and to disintegrate it, in order to produce a material fit for making concrete buildings. Secondly, for doing away with what are known to blast-furnace proprietors and engineers as slag balls, the necessity of which has been impressed upon the public so often by the enormous heaps of slag lying in the neighborhood of iron districts; and also to get rid of the enormous cost of keeping in repair the slag bogies for trucks and the slag boxes. Mr. Wood has had this machine at work now for several months, and has produced 7,000 or 8,000 tons of this material, all of which has been employed in very important works for concrete for drainage, for building concrete houses, and for top dressing for roads over which there is not a very heavy traffic. Mr. Wood showed several specimens of concrete and slag made from this material. Mr. Wood also exhibited a machine for a second process, called by him the "Slag Sanding Machine," by which the whole of the output of slag runs into a bath of water. This water, by the construction of the machine, is kept in a violent state of agitation, and as the liquid slag flows in, it is caught by the agitated water, and distributed in minute particles. The water is kept in agitation by a kind of churn in boxes or screens on the inside, which separates the granulated slag from the water; when carrying it up to the top it drops into a spout, from whence it passes into the railway trucks. It will at once be seen that by this process the slag is put into a shape by which it may be made use of for many purposes, and it also saves the cost of the wear and tear of the iron bogies, the slag boxes, and the annoyance of the liquid slag bursting about the works, which causes so much destruction to life and property. Mr. Wood submitted a box of this slag sand, also specimens of cement of very great strength made from it, comprised of one part of sand to five of lime. He also exhibited some concrete bricks which are made from the same materials simply by mixing this slag with a small quantity of lime under very heavy pressure, and there can be no doubt that these bricks must replace millions made on the old plan. The chief source of demand, however, to be looked forward to is that for manure for the farmers. As the slag contains all the asserted parts of a good manure for heavy lands, not only the chemical but the mechanical properties of the slag sand has a tendency to keep the land open.

In the discussion which followed, several members expressed the opinion that great advantage would result from the general adoption of some such method as that which Mr. Wood had explained to them.—Mr. Wood, in reply to a question, stated that the cost of the bricks made from this material was from 10s. to 12s. per thousand.

RAILWAY NOTES.

RAILWAY SIGNALLING.—One of the most important applications of electricity is to the various devices for the prevention of accident on our railways. Although many mechanical apparatus have been invented, the peculiar nature of the electric current would appear to warrant the assumption that mechanical contrivances can be of value only as auxiliaries to the electrician. We have been favored with a description of the Electric Semaphore Block Signalling Instrument, which has been devised by Messrs. F. Russell for

adaptation to the existing block system. It consists of a case, on the top of which is mounted a miniature post, having one, two, or more semaphore arms, discs, or cross-arms, as occasion may require. The arms or discs are painted similarly to the out-door signals. On the top of the case, in front of the column, is a switch or spring lever, working in a quadrant, which serves to throw the battery current in connection with the line wire. The spring on this lever is sufficiently strong to prevent any accidental movement. In the front of the instrument is a "tapper" or ringing key for ringing the bell at the distant station—the bell being in the lower part of the case. The case measures 14 in. × 11 in. × 9 in. high, and the column stands 18 in. above the case.

The position of the arms is made to represent the state of the line to which they refer, "Blocked," or "Clear," as the case may be. A signalman who understands the outdoor signals thus necessarily understands the electric signals. Each man sees on his own semaphore the position in which he has placed the arms at the other station. The red arms can only be lowered by the signalman at the station towards which the train is approaching; while the white arm is moved by the switch of its own instrument.

The signals used to indicate "danger" and "all clear," to the signalman are the same as those exhibited to the driver. The normal state of the instrument is with the arms raised to "danger." The arms remain at "all clear" so long as a current is flowing from the battery to the line; but the moment the current is cut off, the arms fly up to "danger" the whole apparatus being in equilibrium. It is impossible to lower the arms except by the action of the electric current, and to maintain that signal except by the persistent effect of the battery at the other station. The signal therefore, it will be seen, is solely under the control of the signalman toward whom the train is approaching. The signal cannot be reversed either by lightning or any other atmospheric disturbance. Only one battery is required to work the arms and bell signals for a pair of roads. There are no reversing currents employed, and the battery is being used only while the position of the arms is at "all clear." Any rupture of the line wire immediately throws the arms up to "danger." The semaphores may be constructed so as to be placed perfectly at the command of the platelayers on the line. No battery would be required, but only a few feet of wire, and after the line was again ready for traffic, the red arms could be lowered again.

Another method of securing safety to the railway passenger has been provided by the electric signals and train registering apparatus of Mr. W. R. Sykes and Mr. F. R. Francis. By this arrangement it is impossible for two trains ever to be between two stations, as the signals are worked by each train in advance. In this system suitable springs are fixed to the rails at certain points, of sufficient strength to resist the weight of a man, but not sufficient to oppose the weight of a carriage or other conveyance, and are permanently secured at one end, the other end being fitted to work in a socket, perfectly insulated from the rails, with which, on a carriage or other conveyance passing over the spring, a contact is made, causing an electric current to pass to electro-magnets in the signal lamps, or in connection with the signal-arms, and by their attractive power a double diaphragm of green and red glasses is made to give a red light, or, in the case of arms, place the signal at "danger." This having been done at two points of the line, on reaching the third point the signal here is placed at "danger," whilst the two former are put to "line clear." For example, a train leaving station A with the clear signal, passes over No. 1 spring in connection with the same, and instantly puts it at "danger;" on reaching No. 2 spring it acts in the same manner, putting the signal there also at "danger;" it then proceeds to station B, and on passing out of this station it passes over No. 3 spring in connection with the lamp or signal-arm at that station, placing that at "danger," and at the same moment putting the two former signals at "line clear," thus enabling another train to leave station A, working its signals as did the first train. On arriving at station B, should the signal there be found at "line clear,' it is certain that the first train must have passed the third station, and the second train could proceed in safety. By the adoption of this new system, no signalmen are required at any stations other than at termini and junctions.

The use by railway companies of a means of communication between passengers and guards in railway trains has long been compulsory, but no definite plan has been selected. Cord communication has been condemned, and the various systems of electric signals are still open to improvement. One of the most recent electrical apparatus has been lately applied to a Great Eastern railway train running between Victoria Park and Stratford Bridge. The innovation is upon Colonel Binney's system. The conductors consist of a couple of wires carried along the roofs of the carriages. Each guard's van is provided with an electric bell. One terminal of each bell is connected to one pole of each battery, the other terminal being connected to one of the train wires passing along the tops of the carriages. The other train wire is connected to the second pole of the battery, so that no current of electricity can pass until the two train wires are connected together. To effect this a communicator or "push" is placed in each compartment of every carriage, and which is used when passengers require to give an alarm to the guard.

ENGLISH VS. AMERICAN RAILWAYS. — The London "Railway News" has interesting comparisons of English and American railway returns, and in the matter of rolling stock and train earnings is surprised to find the American roads more economically run than the English. Taking four roads in each country, aggregating about 4,000 miles, it is found that the American road has only .33 of a locomotive and 6.72 freight cars per mile, while the English has .93 of a locomotive and 28.83 cars. The New York Central, with a heavier traffic than the London and Northwestern, has half the locomotives per mile. The English refuse to believe that the superior size and strength of American locomotives account fully for this difference. The earnings, for instance, of an American locomotive are 70 per cent. more than those of an English, and the entire rolling stock, which in England barely pays for itself in a year, in this country pays for itself and 65 per cent. more.

The "News" also discovers that while passenger fares are 30 per cent. lower than in England, the earnings per train here are 4 per cent. more, and on freight trains 15 per cent. more. The "News" concludes that it is time for English managers to study the American way of doing things.

WOODEN RAILWAYS.—There are upwards of 100 miles of wooden railway in operation in the province of Quebec (Canada). The gauge is 4 ft. 8½ in. The running time is about 16 miles per hour, but trains have been run at the rate of 35 miles per hour over these humble but useful lines. The rails are made of maple, 4 ft. by 7 in.; they are set up edgeways, and are notched into cross-ties 4 in. deep, and are held down by two wedges in the notch on the outside of the rails. The ties are 8 in. thick, and they are laid 20 in. apart. The cars have four wheels, and some of the engines used weigh 30 tons. In frosty weather the driving wheels have less adhesion than on metal rails, but no considerable difficulty is experienced from this cause. The rails will last from two to four years, according to the quality of the timber used, and the amount of traffic obtained and accommodated.

WEIGHT OF RAILROAD IRON PER MILE.—A correspondent of the Baltimore "Underwriter and Economist" gives the following rule for calculating the weight of iron per mile of railroad track and the reason for it: Multiply pounds per yard by 11 and divide by 7; the quotient is tons per mile. It is only a problem in simple fractions. In one mile of railway there are 1,760 yards—3,520 yards lineal in the two tracks. Hence the pounds per yard multiplied by the number of yards gives the total weight in pounds. This total divided by the pounds in a ton, 2,240, gives the weight in tons. But, multiplying pounds per yard by 3,520, and dividing by 2,240 is the same as multiplying by 11 and dividing by 7. That is, the fraction 3,520-2,240 reduced to its lowest terms (say by dividing both members by 32) is equal to 11-7.

ENGINEERING STRUCTURES.

THE SAINT GOTHARD TUNNEL.—The acounts of the progress of this great work to the end of March are satisfactory. According to the accounts of the Swiss Federal Council the driftaway had been driven on March 31 to the extent of 252 metres, enlarged to its full size along 210 metres, and the masonry finished over a distance of 103 metres. The average number of men engaged in the work during the month was 617, and the maximum number 813. On the Gœschenen side the tunnelling is through granite, or a hard gneiss, more or less faulty, and full of fissures. On the last day of March the first experiment in mechanical perforation was made with the machines of MM. Dubois et François. The operation took place on the Airolo side, through a schist in beds of unequal thickness. At the distance of 148 metres from the mouth the temperature of the air was 13 deg. c. and of the water 70 deg. c., the air outside the mouth of the tunnel showing a temperature of 7 deg; at 162 metres the air rose to 17 deg. c., when the outer air showed 9 deg.

The infiltration, which was trifling at first, grew in proportion as the increase of the mica and the diminution of quartz, and the frequency of argillaceous beds between the mica and schist, all of which circumstances, of course, diminish the consistency of the soil excavated. The quantity of water augmented considerably at the point of 164 metres; a stream broke in at the rate of more than 16 gallons per second, and disintegrated the rock to such an extent that several slips occurred, and the work was suspended in consequence for some days. At the end of March the outfall of water at the mouth of the tunnel was found to be equal to 9 gallons per second.

ORDNANCE AND NAVAL.

TORPEDO EXPERIMENTS AT STOKES BAY.—The work of raising the unexploded torpedoes in Stokes Bay, near Portsmouth, is progressing. It is found that the explosion of a 500 lbs. gun-cotton charge has destroyed the nearest torpedo at a distance of 80 ft., and that torpedoes 120 ft. distant have been seriously injured. Should this prove to be the limit of destructive range as affecting neighbouring mines it will be necessary in practice to double this distance in placing torpedoes in position. Thus, to defend a wide expanse of water, it will be necessary to plant the mines in serrated lines or other formations, which will prevent the passage of ships while admitting of single explosions being made without detriment to the mines in their vicinity. The iron cases injured are so thin as to afford little indication of what would occur to the bottom of a ship at the same distance. But their injury at 120 ft. distance raises a doubt whether the destructive range of large torpedoes against ships is, when well immersed, so limited as has hitherto been supposed.

THE FRENCH AND WOOLWICH "INFANTS."—It is remarkable that the French gun of 34 tons, which strikes a blow one-fifth heavier than the Woolwich "Infant" of 35 tons, is a cast-iron gun, partially lined and hooped with steel. The steel lining extends from the breech as far as the trunnions, and the exterior hooping covers the same space. This limited application of steel for the lining is peculiar, and one which seems of doubtful advantage. Woolwich is sadly exercised by this use of cast iron, and as to the further circumstance that the French "Infant" is a breech-loader, should the French gun outlive the 38th horizontal discharge with 137 lbs. of pebble powder and 820 lbs. shot, the victory over Woolwich will be striking. But, even then, nobody outside the official world will consider 38 horizontal discharges a satisfactory evidence of endurance for a battering gun. The "Manual of Gunnery for Her Majesty's Fleet," 1873, says:—"The number of rounds which have been fired from some of our heavy M. L. R. guns proves that their powers of endurance are most satisfactory (!: 12-in. (25 tons), 359 and 200 rounds; 10-in. (18 tons), 534 rounds; 8-in. (9 tons, 4[illegible]3 and 408 rounds." These rounds were all of diminished and most of them of greatly reduced charges, *e.g.*, a 12-in. bore properly rifled may burn 120 lbs. of powder, but many of the rounds enumerated were with only 55 lbs of pebble powder. Moreover, most of the discharges

took place when the guns were nearly horizontal, and long intervals of time obtained between every few rounds. These are not the conditions of naval battles. To fire 400 rounds in a couple of days' bombardment, at high elevations and with heavy charges, has been no unusual ordeal in war. Yet 200 rounds fired horizontally with half-sized charges, spread over several years, is chronicled in the official manual of naval gunnery as evidence of "most satisfactory endurance." Should the French cast-iron breech-loading guns have no greater endurance than ours, their possessing one-fifth more battering power will not be any great advantage in the day of battle. But are they so brittle as ours?

THE foreign trade of New York in 1872 was carried on in 60,481 vessels, of which 38,488 were foreign and 21,993 domestic. Of the 38,488 foreign vessels, 19,190 arrived and 19,298 cleared. Of the 21,993 American vessels, 10,944 entered and 11,049 cleared. The aggregate capacity of the foreign vessels amounted to 15,004,106 tons, and of the American vessels to 7,393,224 tons, making a total of 22,397,330 tons. The proportion of foreign vessels as to number, therefore, amounts to 63.6 per cent. and as to capacity 67 per cent.; of American vessels 36.4 per cent., and as to capacity 33 per cent.

A LUCRATIVE trade has for some time been carried on without any rivalry, by the American line of steamers between San Francisco, Japan, and China. Now, however, England is about to enter the field in competition, for the announcement is made from San Francisco of the arrival there of the steamer Antonio, from China, with a full cargo and six hundred Chinamen, the pioneer of a new line that is to traverse the Pacific. A multiplication of steamers is all the better for the commerce of San Francisco, but the managers of our American line should look out that their trade does not suffer from the competition.

OCEAN PATHWAYS.—One of the steamship companies running a line of vessels between this port and Liverpool, touching at Boston, has set a good example by adopting the plan known as the "lane route," suggested nearly 18 years ago by the late Prof. M. F. Maury, as a means of obviating the danger of collisions at sea. This plan designates one course for vessels going east and another for vessels westward bound. The part of the ocean traversed by the steamship lines in their voyages is about 150 or 200 miles broad, and it is proposed in the new plan to mark out a lane from this 15 or 25 miles broad, which will at least reduce the present risks. It is further claimed that the lane to the west will be 30 miles shorter than the route generally taken, and some delays from fogs will be avoided, as it passes 100 miles south of Cape Race. Another advantage claimed for the lane system is, that one way it lies along the northern edge of the Gulf Stream, where there is an eddy setting westward often at the rate of a knot an hour. The close of the argument in favor of the system is that the distance from Cape Clear to Sandy Hook will be shortened several hours, and that, while it prolongs the distance to Europe 75 miles, compensation will be found in the greater security and the advantages of the Gulf Stream and fewer fogs. Considering the number of vessels annually crossing and re-crossing the ocean without especial reference, if any, to each other's course, the number of collisions is very small; but they do happen once in a while with terribly fatal consequences, and any plan or system of navigation which has the effect of rendering them practically impossible, would tend to render ocean travel safer than it is now. The fate of many good ships, whose names will recur to the reader, show the necessity for such a reform as that now inaugurated, and we hope owners of bath steam and sailing vessels will unite in giving the system a fair trial.

BOOK NOTICES.

A TREATISE ON THE STRENTH OF BRIDGES AND ROOFS, WITH PRACTICAL APPLICATIONS AND EXAMPLES. By SAMUEL H. SHREVE, M.A., C.E. New York: D. Van Nostrand.

That much valuable material is uselessly employed in carrying out the various engineering works inseparable from the opening of mines, especially in new districts, owing to the inability of those intrusted with the superintendence of the works to apply the requisite scientific knowledge, has long been a subject of complaint amongst the capitalists with whose funds the operations have been carried on; yet it must be admitted that the man possessing the scientific knowledge has frequently had no opportunity of obtaining practical experience, whilst he who has the practical experience has had neither the time nor the money necessary to enable him to study the higher mathematics, without which the majority of the more important works upon engineering subjects are almost unintelligible. In order, however, that a very essential portion of that knowledge which superintendents of works should be ever ready to apply—the knowledge of the nature and method of dealing with the forces he has to contend with, utilize, or provide against—may be within the easy reach of students and engineers who intend to devote themselves to the practical branch of their profession, Mr. Shreve has furnished them with a volume, which they will find to be invaluable, since comparatively little previous knowledge is demanded from those who take it for their guide, whilst the information which it supplies is such as will enable them to undertake and economically carry out any piece of work connected with bridge or roof building which it is reasonable to anticipate they will have occasion to execute.

By way of introduction, the nature of a truss, and of the two kinds of strains to which it is liable, are briefly yet clearly explained, and the three laws upon which the investigation of strains in trusses may be based are stated—the principle of the lever, the resolution of forces, and the equality of moments being treated of in language which the reader cannot fail to comprehend. Then, commencing with the case of a simple truss, supported at the ends, and loaded at the centre only, the author proceeds to show how the several strains are investigated, taking especial care to make the reader thoroughly comprehend the exact nature of the strain in each particular strut, tie, and brace, and to enable him to perform the

necessary calculations systematically and properly. The centrally loaded truss having been disposed of, the study of the next case where the load is assumed to be between the centre and one extremity becomes comparatively easy, as will also that of the succeeding cases of a uniformly loaded truss, and of a truss loaded from one abutment only a portion of its length. It will readily be perceived that the instruction given in the two chapters, the contents of which are thus indicated, will give the practical man such a sound knowledge of the general principles followed in the investigation of the strength of trusses that he will not despair that further study will enable him to deal with every case connected with the construction of small bridges, such as would generally be sufficient in the laying out of mineral lines to a shipping port, and so on, for it is not unsafe to assume that where heavy engineering works are required an engineer who has given special attention to works of a similar class will be employed to superintend them.

But as the student reads more of the book he will feel every confidence that with the assistance of such an abundance of information as is furnished in the remaining chapters of the work, the amount of practical experience to enable him to rely entirely on his own resources will be considerably less than would otherwise be necessary. The third chapter treats of the simple truss with inclined struts and vertical ties subject to the action of a constant and a moving load, and the author then explains the nature and mode of investigating the strength of trusses with vertical struts and inclined ties, subject to constant and to moving loads, the cases given in illustration embracing simple, double, triple and quadruple trusses respectively, and whether with an even or an odd number of panels. In the fifth chapter the student is introduced to the consideration of trusses with horizontal chords, with struts and ties of equal inclinations subject to constant and to moving loads, commencing with the simplest form of Warren girder, and gradually advancing to the more complicated forms in the shape of double and quadruple trusses. The study of the various cases of trusses with horizontal chords and inclined braces, the ties having a different inclination from the struts, subject to constant and moving loads, will not be difficult now that the way has been so far prepared, and by the time the end of the sixth chapter is reached a pretty fair acquaintance with all forms of trusses applicable exclusively, or nearly so, to bridges, will have been obtained. The same principles govern the investigation of strains in inclined as in horizontal trusses, and moments are taken and equations formed in the same way. The inclined truss thrusts horizontally as well as vertically against its abutments or walls, or the latter may be considered as having a horizontal reaction inward as well as a vertical reaction upward. In the seventh chapter the several kinds of reactions to be considered in connection with trusses of this form, which will, of course, be recognized as roof trusses as contradistinguished from bridge trusses, which have been treated of in the preceding chapters, are carefully and clearly described, and triangular trusses are then dealt with, every information being given for enabling the student to investigate the strains in every modification of this form of truss, and determine the relative advantages of them for any particular purpose to which he may desire to apply it. The succeeding chapter treats of bow-string trusses, which enter into the composition of some of the lightest and most elegant large-span roofs, and are seen in some of the most beautiful bridges in the world; the single truss with vertical and inclined braces, the corresponding compound truss, the simple truss, with all the braces inclined, and having equal horizontal extent, and the corresponding double truss being in turn treated of, whilst the four remaining chapters are devoted to the consideration of lenticular or Pauli trusses, the Kuilenberg truss, the Bollman and Fink trusses, and the resistance of materials to compression and tension.

From the unusually clear language in which Mr. Shreve has given every statement, the student will have but himself to blame if he does not become thorough master of the subject, and as none but algebraic processes have been used, the work may be profitably studied by many who are now placed at a great disadvantage for the want of sound knowledge of the scientific principles elucidated, yet whose general education has not been sufficiently cared for to enable them to follow the reasoning of those who have written for more fully prepared readers; and the author may justly be congratulated upon having so thoroughly descended to the level of the general reader's knowledge without thereby lessening the value of the volume by making it either less complete or less reliable than the most aspiring of its predecessors.—*London Mining Journal.*

PROGRES RECENTS DE LA DISTILLATION. Par M. DESIRE SAVALLE. Paris: G Masson. For sale by Van Nostrand.

Improved methods of distillation of molasses, grains, potatoes, wines; the process of distillation from sugar cane directly, and fractional distillation of benzol, are treated at length and with full illustrations.

LA SEINE. Par M. BELGRAND. Paris: Dunod. For sale by Van Nostrand.

The sources of supply, the rate of flow, fluctuations of level, and character of material conveyed by the Seine seem to have been subjects of patient study, to have yielded such voluminous results as are afforded by this volume. In reality the complete hydrology of a large area of densely populated country is faithfully recorded with scientific precision, and furnishes a good model for similar surveys and compilations in our own country when growth shall demand it.

The maps and charts alone fill a large quarto, and are excellent studies by themselves.

TRAITE DE MECANIQUE GENERALE. Par H. RESAL. Paris: Gauthier-Villars.—For sale by Van Nostrand.

The volume at present before us devotes four hundred and fifty pages to "Cinematics, General Theorems of Mechanics, and equilibrium and motion of solid bodies." A second volume is to deal with the statics and dynamics of fluids and semi-fluids.

The higher mathematics are largely employed in the demonstration of the numerous theorems,

and when it is understood that the work is only introductory to "Industrial Mechanics,' the reader will not accuse the author of unseemly brevity in the treatment of his subject. The cuts are distributed through the text.

Students who desire to acquire the methods of analytical investigation through the aid of the calculus will find M. Resal's treatise of special value.

ETUDES SUR LES FORCES MOLECULAIRES DANS LES LIQUIDES ÊN MOUVEMENT ET APPLICATION A L'HYDRODYNAMIQUE. Par M. KLEITZ. Paris: Dunod. For sale by Van Nostrand.

This is strictly a treatise upon one branch of higher mechanics. The division of the subject by chapters is as follows, viz.:

1. Definitions et principes élémentaires.
2. Lois qui regissent les forces moléculaires superficielles, ou forces elastiques.
3. Vitesses relatives dans les liquides en mouvement.
4. Expressions des forces élastiques en fonction des vitesses relatives.
5. Conditions geometriques qui regissent les directions relatives.
6. Expression des forces élastiques en fonction des variations de la vitesse.
7. Forces de glissement sur les parois qui renferment en liquide en mouvement.
8. Expressions des forces moléculaires rapportées a l'unite de masse.
9. Travail des forces moleculaires.
10. Movement permanent des liquides.

TRAITE DU LEVE DES PLANS ET DE L' ARPENTAGE. Par J. DUPLESSES. Paris: J. Baudry. For sale by Van Nostrand.

A rudimentary treatise on surveying by means of the chain graphometer and plane-table, for the use of young French students, is of interest to instructors who care to study the methods employed abroad in imparting the methods of the surveyor to the pupils in the schools.

The work is of the most elementary character, and deals with the simplest problems only, but always with reference to graphical representation of the results.

Something over a hundred cuts embellish the the book.

ELECTRICITY AND MAGNETISM. By FLEEMING JENKIN, C. E., F.R.S., Professor of Engineering in the University of Edinburgh. (Longmans and Co. 1873.)

This is the new volume of the "Series of Text Books of Sience, adapted for the use of Artisans and of Students in Public and other Schools," issued by the publishers, and edited by Professors Goodeve and Merrifield. It contains 378 pages, is admirably printed and amply illustrated. The style of the contents is eminently practical: it is a book for engineers old and young. The author thought that in England there may be said to be two sciences of electricity—one taught in ordinary text books, and the other a sort of floating science, known more or less practically to practical electricians, and expressed in a fragmentary manner in papers by Farady, Thomson, Maxwell, Joule, Siemens, Matthiessen, Clark, Varley, Culley, and others. The science of the schools is so dissimilar from that of the electrician that it has been impossible to give students even an approximately sufficient text-book. Prof. Jenkin thus says that a student might have mastered Delarive's large and valuable treatise, and yet feel as if he were in an unknown country in the company of practical men, and he thinks that the science known to the practical men was far more scientific than that of the text-books. So the author tells us that he found it quite impossible to write this treatise on the ordinary plan of beginning with simple experiments, and gradually building up a science by the description of a series of more and more complex phenomena, and the plan he has adopted may be briefly sketched as follows:—First, a general synthetical view of the science has been given, in which the main phenomena are described, and the terms employed explained. After giving a very careful account of the laws and especially of the means of measurements of electric condition, the author has given their chief practical application to telegraphy, and a few examples of the construction of telegraphic apparatus. The writer relies on the permanency of the general theory of electricity on which the construction and use of changing forms of apparatus depend, since it depends on no hypothesis; and his aim has been to state this general theory in a connected manner, and in such a simple form, that it may be readily understood by practical men. The design of this work is new and excellent, and the ample index renders it a valuable repertory of facts in electricity and magnetism. It must, however, be admitted that the author has not achieved the high aim in view, for a careful reading of his book does not leave that peculiar impression which is only derived from a work such as Herschel's "Outlines of Astronomy," in which great lucidity of thought has brought to its aid a corresponding felicity of expression. Yet Professor Jenkin's book is undoubtedly an experiment in the right direction. He has had not only his own great practical experience as an electrician, but has had the advantage of assistance from Sir Wm. Thomson, Professor J. C. Maxwell, at Cambridge, and Messrs. Culley, Varley, etc. In these circumstances the work could not fail to be of the highest quality, so far as facts and forms of apparatus are concerned; and in this respect we can unhesitatingly commend it to all practical men concerned in an important department of engineering.

INTRODUCTION TO CHEMICAL PHYSICS, DESIGNED FOR THE USE OF ACADEMIES, HIGH SCHOOLS, AND COLLEGES. By THOS. RUGGLES PYNCHON, M.A., Scovill Professor of Chemistry and the Natural Sciences, Trin. Coll., Hartford. New York: D. Van Nostrand.

A knowledge of Chemical Physics is almost as necessary to men engaged in general industrial pursuits as it is to those pursuing a strictly scientific course of study, yet until comparatively recently it was difficult to obtain anything like a satisfactory acquaintance with the subjects included under that designation, except from an extensive course of reading, necessitating the investigation of various allied matters, which it was not anticipated would be subsequently required. The system, then, of treating chemical physics as a separate branch of science was undoubtedly a

sound practical improvement, since it has enabled a large number of persons to acquire information likely to be useful to them, without compelling them to study that which they do not want; and Prof. Pynchon's Introduction, although designed more especially for the use of educational establishments, will fully meet the requirements of nine-tenths of the readers amongst manufacturers to whom familiarity with the subject could be turned to account. Prof. Pynchon's volume embodies the most important facts and principles of the physical forces—heat, light, and electricity—connected with the production of chemical phenomena, and is also designed to form an introduction to the science of chemistry, to the satisfactory study of which a thorough knowledge of them is, indeed, absolutely indispensable.

In connection with telegraphy, the generation of steam, electro-metallurgy, photography, and numerous other processes in every-day use, the principles of chemical physics are constantly applied, and it cannot be doubted that those who best understand those principles can most effectively apply them. As Professor Pynchon truly remarks, the merit of a work of the class to which his belongs must consist rather in the judgment shown in the selection and arrangement of materials than in the originality of the contents, it may be well to endeavor to give a brief outline of the contents of the volume. In the introductory chapter the origin of the name and the nature of chemistry are thoroughly explained, and the properties of matter are then elucidated, every care being taken to point out what properties are treated of by natural philosophy, and what by chemistry. The history of chemistry is briefly sketched, and reference is made to the fundamental principles of the science, to the apparatus used, to the constitution of some of the most important chemical compounds, to the chemical agents—heat, light, and electricity—and why they are called imponderables, and to other similar elementary matters, a knowledge of which is required for the more profitable study of the succeeding chapters. The chapter on the first chemical agent—heat—is as complete a treatise on the subject as is found in the best college text-books devoted to the subject, and, although concise, the style is by no means uninteresting; the diffusion of heat-expansion, liquefaction, ebullition, evaporation, specific heat, sources of heat, nature of heat, are each treated of, the explanations being rendered particularly clear by the admirable illustrations by which they are accompanied. Light and electricity are dealt with in an equally complete and satisfactory manner, ample details being given with regard to the nature of light, its sources, reflection, refraction, the solar spectrum, spectrum analysis, the effect of light, and the relations of light and heat; whilst in the chapter upon electricity there are very full sections upon statistical and galvanic electricity, electro-magnetism, magneto, thermo, and animal electricity, and the relations which the several chemical agents bear to each other.

To attempt an epitome of a volume so concisely written as that at present under consideration would be out of the question, but a fair notion of the style of the work may be gained from the perusal of a single article, that of spectrum analysis. —*London Mining Journal.*

MISCELLANEOUS.

SOME interesting notes on early chemistry have appeared in "Nature." From them we collect the following as to iron: "Iron was not in common use till long after the introduction of copper. It is far more difficult to procure, because it is not met with in the native state, and the fusing point is very high. The metallurgy of iron is more complex than that of copper, and when obtained it is a more difficult metal to work. According to Xenophon the melting of iron ore was first practised by the Chalubes, a nation dwelling near the Black Sea; hence the name Chalups (χάλυψ) used for steel, and hence our word *chalybeate* applied to a mineral water containing iron. Steel was known to the ancients, but we do not know by what means it was prepared: it was tempered by heating to redness and plunging in cold water. According to some kuanos (κυανος) mentioned by Homer was steel; but Mr. Gladstone prefers to conclude that it it was bronze. Iron was known at least 1537 B. C. It was coined into money by the Lacedæmonians, and in the time of Lukourgos was in common use. It was used in the time of Homer for certain cutting instruments, such as woodmen's axes, and for plough shares. Its value is shown by the fact that Achilles proposed a ball of iron as a prize for the games in honor of Patroklos. Neither iron money nor iron implements of great antiquity have been found, because, unlike the other metals of which we have spoken above, iron rusts rapidly and soon comparatively disappears. No remains of it have been found in Egypt, yet Herodotus tells us that iron instruments were used in building the pyramids; moreover, steel must have been employed to engrave the granite and other hard rocks, massive pillars of which are often found engraved most delicately from top to bottom with hieroglyphics. Again, the beautifully engraved Babylonian cylinders and Egyptian gems, frequently of cornelian and onyx, must have required steel tools of the finest temper. We have no record of the furnaces in which iron ore was smelted, but we know that bellows were in use in the 15th century B. C. in Egypt, and some crucibles of the same period are preserved in the Berlin museum. They closely resemble the crucibles in use in the present day." We may add that Mr. Layard found an iron saw at Nineveh.

SILICATE PAINTS.—The result of trials made of the silicate paint manufactured by the Silicate Paint Company, appears very satisfactory, all who have used it speaking strongly in its favor. All of our readers may not know that the basis of the paint is a remarkable deposit of almost pure silica in North Wales. The proprietors submitted it to several chemists, whose analysis demonstrated that it would be of peculiar utility as a substitute for white lead in the manufacture of paint. Results have proved the correctness of this view, and the silicate paint, while less costly than the ordinary white lead paint, has favorably impressed those who have used it. It entirely resists the effect of heat, and is especially suited for use on materials exposed to the action of the weather or salt water, especially iron, there being no galvanic action, as with lead paint.